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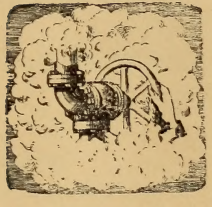

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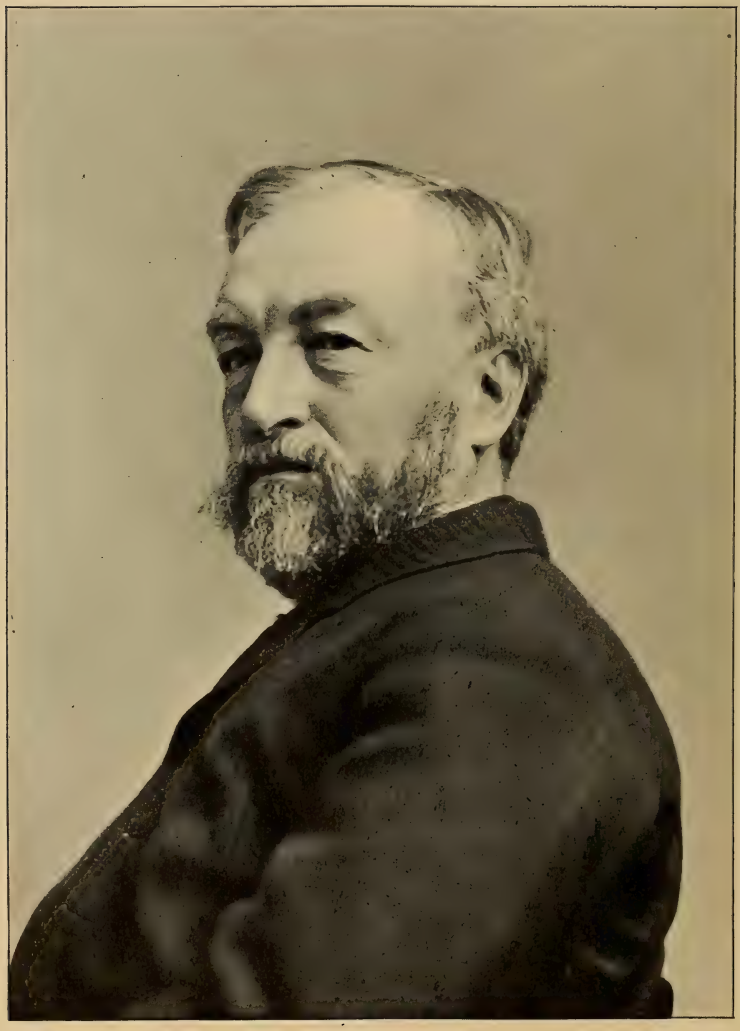

SAMUEL PIERPONT LANGLEY

SECRETARY OF THE SMITHSONIAN INSTITUTION, WASHINGTON, D. C.

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CASSIER'S MAGAZINE

VOL. XXV NOVEMBER, 1903 No. 1

THE IMPERIAL GERMAN NAVY

By Archibald S. Hurd

NO country in Europe offers so fascinating a subject of study as the empire of Germany, a little over thirty years old only, and in no particular does this, the youngest of the Continental powers, present more remarkable signs of awakening than in respect to its navy. In the contest for supremacy, in which practically all nations with one or more outlets to the sea are now joining with such energy, there promises to be no phase more interesting than the competition between the German and American navies for the position of the world's

THE CRUISER "KAISERIN AUGUSTE" PASSING THROUGH THE KAISER WILHELM CANAL

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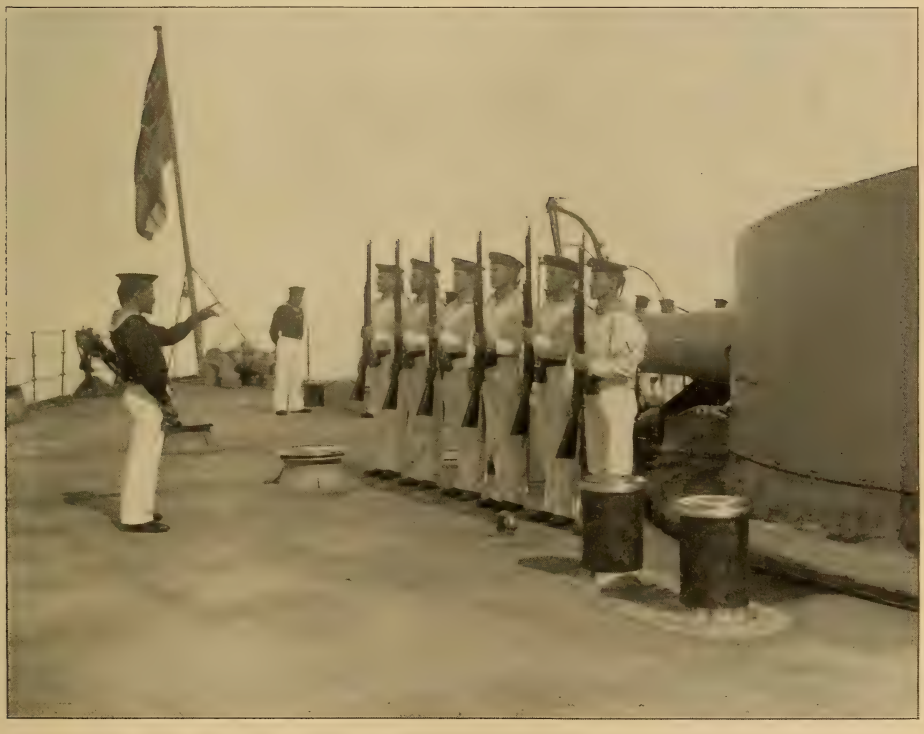
THE ARMOURED CRUISER "PRINZ HEINRICH"

second greatest naval power. The progress of the struggle as seen on paper will be revealed by the number of ships possessed by these two countries, but the vital struggle will be far deeper than this and will embrace many subjects,—relative wealth, organisation of ships and men, administrative efficiency, war-training, strategical advantages and disadvantages, the benefits and drawbacks attaching to a democratically governed force on the one hand and one controlled by one of Europe's most powerful autocrats on the other. Adequate consideration of this German-American contest for the titular position of the world's second greatest naval power and the relative position of the victor to the British fleet in the years to come, cannot be given within the limits of this article, the aim of which is more modest—to trace the growth of the German fleet, which Kaiser Wilhelm II. has recreated since he ascended the throne. By its situation in Central Europe and by the pressure of the lessons of history, Germany has been forced into her position as the predominant military power of Europe, with over two and a half million trained men to call upon in time of war. The Teuton is blessed—or cursed—with a fierce love of fighting allied with the genius of organisation for war while yet not a cloud darkens the sky. What the German army was in 1870, that and better it is to-day in spite of the depression of agriculture, the growing importance of manufactures, the swift immigration of the country-bred into the urban districts, and the unpopularity of conscription.

Similarly by her situation in Central Europe and the pressure of the lessons of history, Germany in the past has been forced into the position of a minor naval power. Nature helped to stifle any hopes of great maritime glory in the people of the Empire. It is cooped up. Apart from the Baltic, which is, in a measure, shut off from the outside world,

Germany has only a small coast-line facing the North Sea, and for the whole length, practically, it is defended against the marauder by a string of islands and stretches of sand, rendering approach by an enemy's big ships not only difficult, but well-nigh impossible. The estuaries of the rivers Ems, Elbe, Weser, and Eider that debauch into this sea can be defended by fixed guns at a small expense, and some coast defence ships in the Baltic with inexpensive shore defences can secure Germany from attack there. An insignificant fleet, consisting mainly of small ships, completed Germany's scheme of defence — ture by the aid of the engineer and righting the faults of her situation and past development with the assistance of the diplomat. The Kaiser Wilhelm Canal has been cut through from the Baltic to the North Sea, enabling a fleet to be moved from the one sea to the other in a very short time; Heligoland has been ceded by Great Britain and is now armed and defended as Germany's advanced sentinel in the North Sea; the small oversea possessions have been expanded as the result of a determined policy, and by sops to this party and to that it has been possible to obtain the nation's consent to a great scheme of



GOING THROUGH THE MANUAL OF ARMS

for fifteen years ago her naval policy was purely defensive.

That was the position, but it exists no longer. Unfitted by the configuration of her territory for naval ascendency Germany, under the strong guidance of Kaiser Wilhelm, has been busy for fifteen years past in improving upon naval augmentation which will result in the fleet, as it existed in 1898, being doubled in numbers of ships and men and considerably more than trebled in fighting power. The coast defence ships are being replaced by battleships, the small dockyards by great arsenals, and in distant seas the German ensign is flown.

CLEANING SHIP AFTER COALING

PHOTO BY A. RENARD, KIEL

The watchword of the German fleet from the Kaiser downwards is concentration—concentration of the ships in the North Sea, concentration of the officers and men on their training for war, concentration of the administration on the problems which a naval war will present and on the provision of the instruments best suited to the work which they will have to do. The ships are big, but not too big for manœuvring on the shallow coastline of the North Sea; the officers and men are trained in the scientific side of naval warfare, but not to the detri-

ment of practical sea experience; the fixed defences of the national arsenals are being developed, but not so as to starve in the slightest degree the fleet itself, the Empire's mobile offensive-defensive weapon, which is held to be the necessary corollary to a world policy, an Empire over-seas and a great export trade.

The naval expansion may be said to date from the year 1898, but the proposals were expanded and took permanent shape two years later, when the nation ratified its determination to raise Germany to one of the world's major powers afloat. The Navy Act provided for doubling the size of the fleet and for the automatic replacement of all the older ships by larger and more powerful ones. The following is the programme which was to be completed by 1916, but the work has been so hastened that the maximum strength of the fleet will be reached before that year:—38 battleships, 14 large cruisers, and 38 small cruisers. In accordance with the emperor's scheme, six more large cruisers and seven smaller ones were demanded for use on foreign stations, but this portion of the programme could not be carried through the Reichstag, and for the present it has been dropped, but only for the time. The Navy Act also made provision for augmenting the personnel,—the officers from 1285 to 3090, and the warrant and petty officers and men from 21,528 to 55,809,—increasing the facilities for training ashore and at sea, improving the dockyard arrangements and perfecting the equipment of the fleet. In all, the naval expansion scheme is expected to entail an expenditure of over £86,000,000. It is the largest, most elaborate, most carefully thought out and complete scheme ever undertaken, and its provisions are being carried out with more than clockwork regularity, since the ships are being built and completed sooner than was originally intended. The battleship *Kaiser Karl der Grosse* was built and completed for sea in forty months and five days, the *Zähringen* in thirty-five months, and, lately the *Wettin* in thirty-five months and seven days. These are excellent achievements in naval construction.

Possibly the progress which has been made with this scheme so far as it has already been carried out cannot be indicated better than by the tabulated statement on page 9 showing the German fleet as it existed in 1898, the ships which have been completed since, and the ships now under construction.

THE CRUISER "AMAZONE"

SPRUCING UP FOR THE MANŒUVRES

PHOTO BY A. REWARD, KIEL

German naval policy is revealed by the mere list of ships which are now being built. Her aim is the antithesis to that of France. The latter country, until 1901, had been neglecting the heavy fighting ship and spending her naval funds largely on corsairs and submarines. Germany has no faith in such a policy, nor does she follow in the footsteps of Great Britain and the United States in the matter of huge battleships. She pins her fortunes to the battleship of moderate dimensions and on a small displacement arranges a heavy gun-power, and except as scouts to the great fighting ships she spends little or no money on cruisers. She has four armoured cruisers of just over 9000 tons in hand, but one searches in vain for leviathans of 14,100 and 14,800 tons which figure in the plans of Great Britain and the United States. Ger-

PROGRESS OF THE GERMAN FLEET

BATTLESHIPS

Completed 1898				Completed 1903				Building 1903			
Class	No.	Type and Date	Displacement Tons	Class	No.	Type and Date	Displacement Tons	Class	No.	Type	Displacement Tons
1st	4	Brandenburg (1891–92)	10,062	1st	5	Kaiser (1896–1900)	11,152	1st	2	Wittelsbach	11,643
3d	1	*Oldenburg (1884)	5,118	1st	3	Wittelsbach (1900–1)	11,643	1st	6	Braunschweig	13,000
2d	4	*Sachsen (1877–80)	7,368								
3d	2	Deutchland (1874)	7,676								
3d	8	*Hagen (1889–95)	3,474 to 4,048								
3d	1	König Wilhelm (1868)	9,603								

COAST DEFENCE SHIPS.

—	11	Wespe (1876-81).	None.		None.

——— * The Oldenburg was reconstructed in 1895–6; the Sachsen type in 1897-9, and lengthened; and the Hagen type are now in process of reconstruction and lengthening

ARMOURED CRUISERS

Completed 1898				Completed 1903				Building 1903			
Class	No.	Type and Date	Displacement Tons	Class	No.	Type and Date	Displacement Tons	Class	No.	Type	Displacement Tons
		None	------	1st	1	Prinz Heinrich (1900)	8,759	1st	4	Prinz Adalbert	9,348
			------	1st	1	Furst Bismarck (1897)	10,482				

PROTECTED CRUISERS

1st	1	Kaiserin Auguste (1892)	5,956	2d	5	Hertha (1897–98)	5,569 to 5,791	3d	7	Frauenlob	2,672 to 2,952
2d	2	Irene (1887–8)	4,330	3d	7	Gazelle (1898–1900)	2,617				
2d	1	Gefion (1893)	4,044	3d	1	Frauenlob (1902)	2,672				
3d	*a* 2	Wacht (1887)	1,230								
3d	1	Hela (1895)	1,971								

a One lost at sea, 1901

UNPROTECTED CRUISERS

Completed 1898

No.	Type and Date	Displacement Tons
6	Falke (1890–94)	1,555 to 1614
1	Greif (1886)	1,968
2	Alexandrine (1885)	2,335
1	Charlotte (1885)	3,171
1	Nixe (1885)	1,732
2	Blitz (1882)	1,360
4	Olga (1880–81)	2,135
3	Moltke (1877–78)	2 810

In 1903 there were none of this type, either completed or building

TORPEDO CRAFT

	Completed 1898	1903	Building 1903
Vessels	2 (931 tons)	none	none
Boats	113	none	none
Destroyers	1	28	10
Submarines	none	none	none

SUMMARY OF GERMAN NAVY, 1893–1903

	Built 1893	Built 1903	Building	Total Built and Building in 1903
Battleships, 1st class	4	12	8	20
" 2d "	4	4	--	4
" 3d "	12	12	--	12
Coast Defence, vessels	11	11	--	11
Cruisers, Armoured	--	2	4	6
" 1st class	1	1	--	1
" 2d "	3	8	--	8
" 3d "	3	11	7	18
" Unprotected	20	20	--	20
Torpedo Vessels	2	2	--	2
" Boats	113	93	--	93
" Destroyers	1	28	10	38

THE BATTLESHIP "ZÄHRINGEN"

A GUN CREW POSING FOR THE CAMERA

PHOTO BY A. RENARD, KIEL

many knows that she has not a long purse and she knows that the next naval war will be decided by battle actions. Since she cannot afford to prepare for the sea fight and also make provision for protecting her commerce with war cruisers, she concentrates attention on the battle which will decide the issues of a quarrel, and her armed merchantmen will have to render what aid they can to her shipping. Unlike the French nation, harassed by every wind of criticism, the emperor has weighed all the pros and cons and he has determined on his policy. Instead of repining at his comparatively limited resources, he is cutting his coat according to his cloth. Medium-sized battleships of great power, good speed and adequate protection, with a few large armoured cruisers as the vanguard and a swarm of small scouts of under 3000 tons, swift and cheap—these are held to meet the needs of Germany,

TABLE I.—SOME OF THE WORLD'S LARGE BATTLESHIP DETAILS

Country	Type	Displacement Tons	Speed Knots	Armament			
Great Britain	King Edward VII	16,350	18.5	4 12-in.	4 9.2-in.	10 6-in.	24 small
United States	Louisiana	16,000	18	4 12-in.	8 8-in.	12 7-in.	38 small
France	Republique	14,692	18	4 12-in.	---------	18 6.4-in.	28 small
Russia	Borodino	13,600	18	4 12-in.	---------	12 6-in.	46 small
Germany	Braunschweig	13,000	18	4 11-in.	---------	14 6.7-in.	32 small
Italy	Regina Elena	12,624	22	2 12-in.	12 8-in.	---------	24 small

TABLE II.—THICKNESS OF BATTLESHIP ARMOUR

Country	Type	On Guns	On Water-line
Heaviest British Armour,	King Edward VII	12 in.	12
" " "	Russell	11 in.	10
" American Armour,	Louisiana	12 in.	14
" French "	Republique	11 in.	15
" Russian "	Borodine	11 in.	12
" German "	Braunschweig	10 in.	12½
" " "	Wittelsbach	10 in.	13
" Italian "	Regina Elena	8 in.	14

THE CREW OF THE BATTLESHIP "KAISER WILHELM DER GROSSE" AFTER COALING

PHOTO BY A. RENARD, KIEL

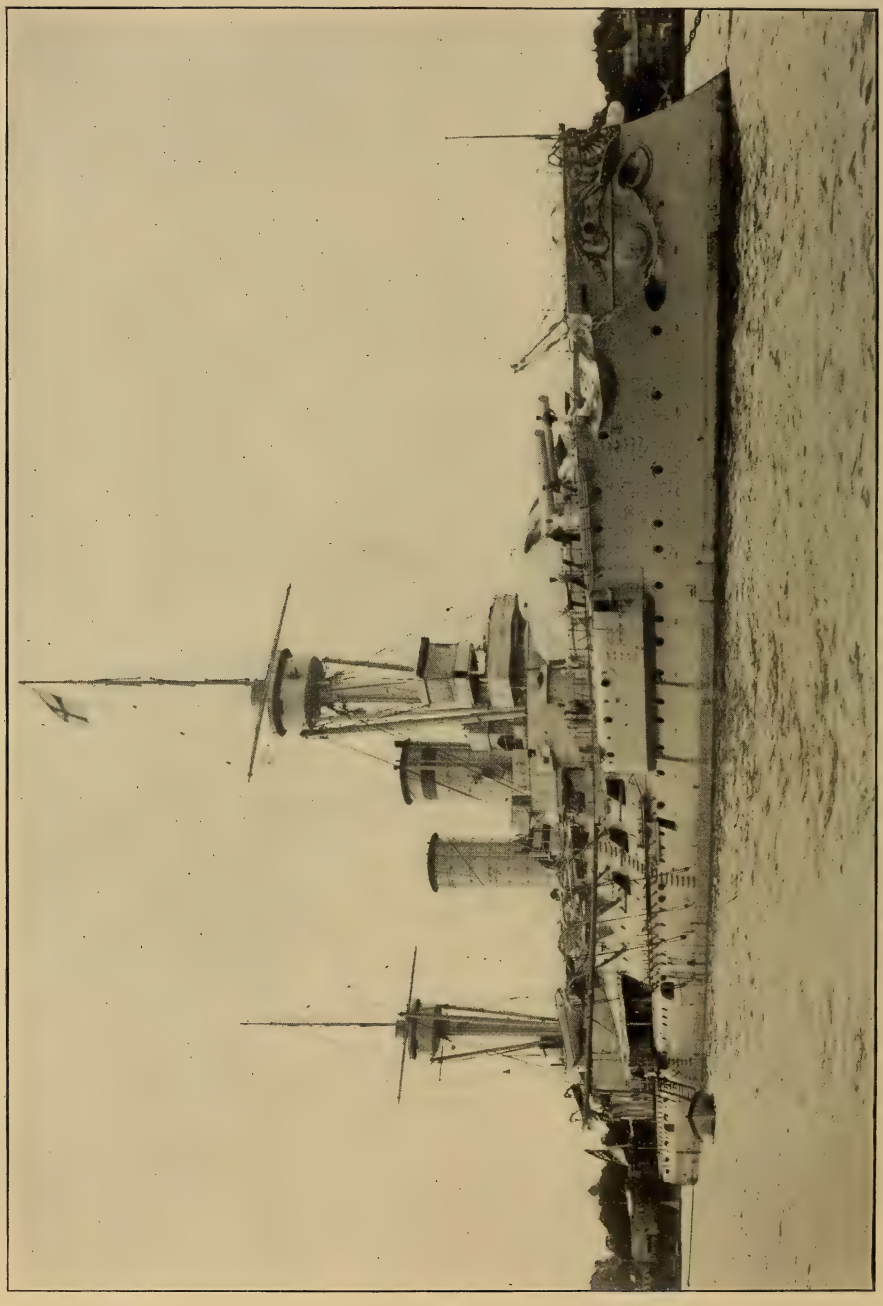
and in this manner she is preparing. The ships of the German navy have moderate draught, for use in the North Sea and passage through the Kaiser Wilhelm Canal, but since the idea of the emperor is that the naval battle will be short and sharp, he concentrates ever-increasing attention on the training of the gunners and gives to each ship, by developing the secondary armament, a power of attack which is excelled in no other navy in the world. This policy may be illustrated by the details of the largest battleships now building for the great powers given in Table I, page 11.

THE ARMOURED CRUISER "KAISER BARBAROSSA"

These figures indicate what admirable results on a most moderate displacement the German constructors have succeeded in obtaining, of course at the sacrifice of other qualities, for an armoured ship is a compromise. The Germans choose the most practical and self-evident advantages. In the case of the British designers this is frequently not the case. For instance the two battleships *Barfleur* and *Centurion*, ten years old, are just being reconstructed, and by removing a forward mast weighing seventy tons and effecting other economies, it has been possible to replace the ten 4.7-inch guns of the secondary armament by a similar number of 6-inch weapons and at the same time to improve the protection. Economy in weight has not been practised anywhere with as good results as in the German navy.

Turning from the striking power of the ships to their protection from an enemy's guns, it is astonishing to note what admirable results have been achieved. Table II. indicates this, the comparative displacements being borne in mind. In the last column the resistance of the deck and belt combined are given.

These figures again indicate that the Germans are endeavouring to get maxi-



THE "KURFÜRST FRIEDRICH WILHELM"

SAIL SCRUBBING
PHOTO BY A. RENARD, KIEL

mum fighting value out of every ton of displacement, while their battleships are also given a good radius of action. The *Kaiser* class can stow from 650 to 1000 tons of coal, the *Wittelsbach* from 700 to 1450, and the *Braunschweig* from 700 to 1600, while the last-named carries 200 tons of tar oil in addition and all the others are also fitted to store liquid fuel.

The newer German ships have more torpedo tubes than any other vessels in the world, in direct opposition to American opinion which has dictated that the ships about to be built shall have no torpedo equipment. All the German ships have three screws. German opinion strongly favours this departure from the conventional arrangement on account of the improved manœuvring capacity, which, it is claimed, is thereby obtained, an advantage which will be of the most vital importance in a naval battle, especially in comparatively narrow waters.

On these lines the new German fleet

AN HOUR OF RELAXATION

PHOTO BY A. RENARD, KIEL

is being strengthened, while the small ships, which belong to the time when the German Empire had no world policy, are being taken in hand and lengthened and improved so as to fit them better for an open sea action.

In 1906, when the numerical strength of the fleet will have been doubled, the task of replacing the older battleships will be taken in hand, and long before 1916 (in addition to the vessels which will have been built as net additions to the fleet) Germany will have 17 new first-class battleships, 10 large cruisers of the armoured type, and 29 smaller cruisers. Consequently, when the scheme is completed, the first line of the German navy will comprise 38 battleships, the oldest dating back no further than 1898; 14 large and 38 smaller cruisers, and also the ships she possessed in 1898 when she began the great scheme of augmentation.

The bedrock on which the emperor is building is this:—Germany, owing to the many claims she has to meet for her predominating army, her colonies and her protective commercial system, can-

not hope to have a fleet to equal that of Great Britain, but it must be ship for ship more efficient than any navy afloat, and in this manner its inferiority may be minimised and even wiped out. "Germany," to quote from the Navy Act, "must have a fleet of such strength that even for the mightiest power, a war with her would jeopardise its own supremacy."

As has been stated already, the personnel of the fleet is being increased, *pari passu*, as new ships are added, and similarly the training establishments for officers and men are being expanded to meet the new needs. It is the desire of the emperor to possess the best-trained personnel in the world.

"As even after the projected increase has been carried out," the memorandum accompanying the Act states, "the number of vessels in the German navy will still be more or less inferior to that of other powers, our endeavours must be directed towards compensating for this superiority by the individual training of the crews, and by tactical training by practice in large bodies."

It is in accordance with this policy that throughout last winter Prince Henry of Prussia's large squadron remained for the first time in commission cruising throughout the dark months, invading even the English Channel and the Atlantic. In the past these ships would have laid up for the winter. No officers are more hard-working, no men more intelligent than those of the German fleet, and the system of training has been arranged so as to get the best value out of them. It is, of course, true that Germany has a small, very small, seafaring population to draw upon for her crews, but it is a greater truth that in these days of mechanical engines-of-war, this drawback, which would have been serious some years back, is of little account. Mechanicians, rather than sailors of the old type, are required now. Keenly intelligent and devoted to their work, officers and men compel admiration.

In the German navy it is not the ships or the men merely which count, but the spirit which animates the service. It is said that the Emperor William, who is head of the fleet in fact as in name, knows personally each of its officers; it is he who arranges promotions and fills appointments, and even his own brother, Prince Henry of Prussia, cannot settle the cruises of his splendid squadron until his preliminary arrangements have received the approval of the emperor. The German navy is one of the only remaining sea forces animated and personally directed by a sovereign, and visitors to the ships are always struck by the respect, almost awe, in which the emperor is held, the pleasure which his praise occasions, and the terror caused by his slightest frown. The German navy is to-day a great power; ten years hence it will be one of the dominating influences of the world.

SUPERHEATED STEAM FOR STEAM ENGINES

WITH SPECIAL REFERENCE TO THE MC PHAIL & SIMPSONS SYSTEM

By John Goodman, M. Inst. C. E.

AFTER the importance of Hirn's experimental results on superheated steam had been realised, a great many steam users decided to adopt superheated steam in their own plants. That economy in steam and fuel resulted, none will deny; but, nevertheless, one by one they abandoned superheat and returned to saturated steam. Their reasons for doing so will be more apparent after having examined carefully the advantages and disadvantages of using superheated steam in an ordinary steam engine. The writer uses the qualification "ordinary," because special forms of steam engines and turbines are now in use which effectually overcome some of the difficulties met with when using superheated steam in an ordinary steam engine. The vast majority, however, of those who wish to use superheated steam are those who possess only ordinary steam engines and who do not consider that it would be a wise step to reject these engines in favour of special types which will deal more successfully with highly superheated steam. The question of using superheated steam in a steam engine may be stated thus:—

The weight of steam used per indicated horse-power is materially less when the steam is superheated than when saturated steam of the same pressure is used. If the consumption be taken as 100 for saturated steam, it will be roughly as given in the table in the next column, when superheated.

In other words, each 50° of superheat in a reciprocating engine reduces the former consumption by about 10 per cent., and by 5 per cent. in the case of a turbine, which is in inverse proportion to the volume of the steam or to the absolute temperature. This must be taken only as a rough approximation, but it, nevertheless, agrees tolerably well with the results of experiment.

Superheat at the Engine	Consumption	
	Turbine	Reciprocating Engine
0	100	100
50° F.	95	90
100° F.	90	81
150° F.	86	73
200° F.	81	66
250° F.	77	60
300° F.	73	53
350° F.	69	48
400° F.	66	44

This economy is largely due to the fact that the temperature of superheated steam is considerably above its saturation or condensing point; consequently when it enters a cylinder cooler than itself and its temperature is thereby reduced, the usual cylinder condensation does not take place until the temperature is reduced to that of saturation. Cylinder condensation is, therefore, largely reduced and if the superheat be sufficiently great, the condensation may be entirely overcome.

The decreased steam consumption is due also to the fact that the volume of the steam is increased by the superheating in amount almost proportional to the absolute temperatures before and after superheating. Since its capacity for doing work at any given pressure varies almost directly as its volume, it follows that a given weight of steam has a greater capacity for doing work when occupying a greater volume than before; consequently a smaller weight of steam is required to do a given amount of work.

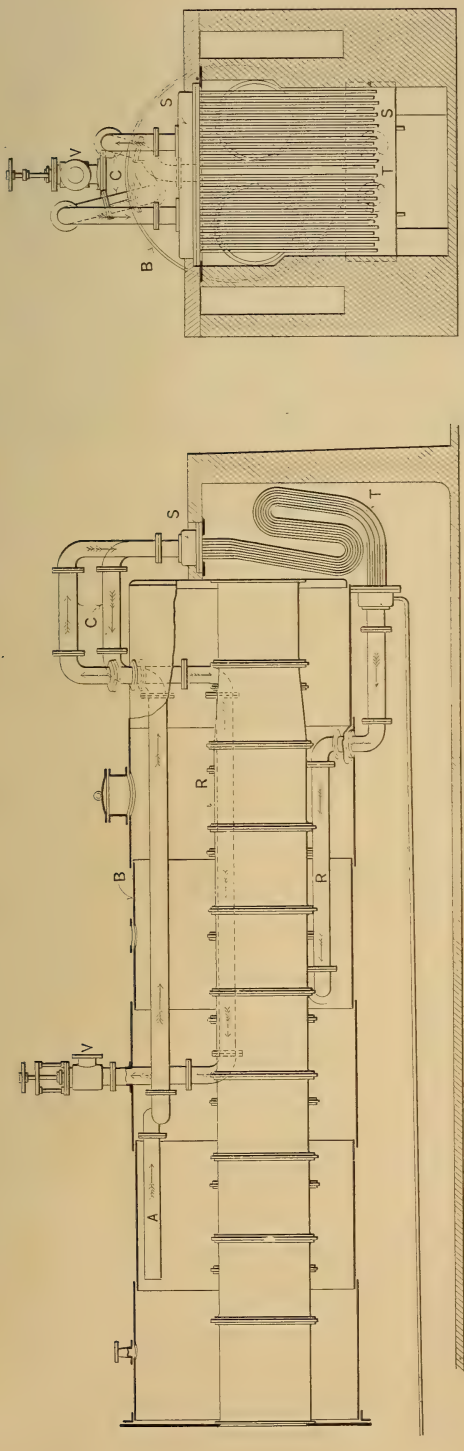


FIG. 1.—ELEVATION AND END VIEW OF A BOILER FITTED WITH A MC PHAIL & SIMPSONS SUPERHEATER. MADE BY MC PHAIL & SIMPSONS' DRY STEAM PATENTS COMPANY, LTD., WAKEFIELD, ENGLAND

A minor advantage, apart from the question of economy, is that the steam supplied to the engine is perfectly dry when it is superheated, and the dangers of priming are thus avoided. Now that so many water-tube boilers are used which nearly always prime badly when forced, the question of getting dry steam, especially with high speed engines, is becoming one of very great importance.

The disadvantages of highly superheated steam are that the steam not only supplies no water of condensation to lubricate the rubbing surfaces of the valves and cylinders, but it decomposes many of the oils that are fed into the cylinder for lubricating purposes; hence the valve faces, cylinders, and pistons are liable to become badly scored; also, the gland packing not unfrequently is burnt or melted out.

It must, however, be remembered that these are troubles which arise only when high degrees of superheat are adopted. Thus, in order to get some of the benefit to be derived from superheating without experiencing the troubles mentioned above, it is necessary, under ordinary circumstances for power purposes, to use only very moderate degrees of superheat, say 100° F. This, however, is a difficult matter to accomplish, unless a special regulator or modifier be used to keep the superheat within any given limits. With many of the superheaters in common use, it will vary a hundred degrees or more in a very few minutes unless it be very carefully watched.

When considering the disadvantages of superheating, the fact must not be overlooked that in a great many cases the superheater tubes have been known to burn out. The burning away of the superheater tubes has occurred in most cases where

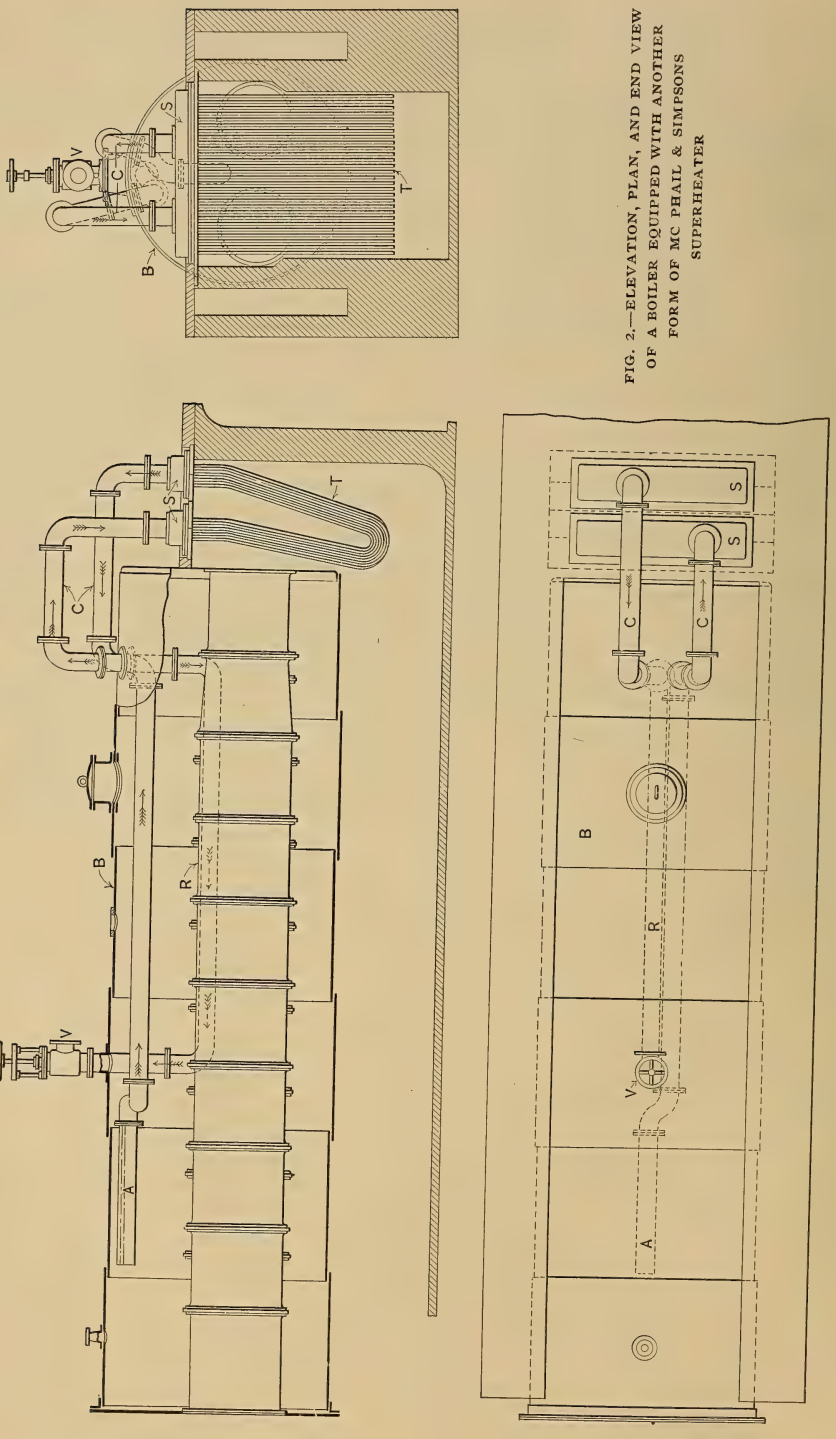


FIG. 2.—ELEVATION, PLAN, AND END VIEW OF A BOILER EQUIPPED WITH ANOTHER FORM OF MC PHAIL & SIMPSONS SUPERHEATER

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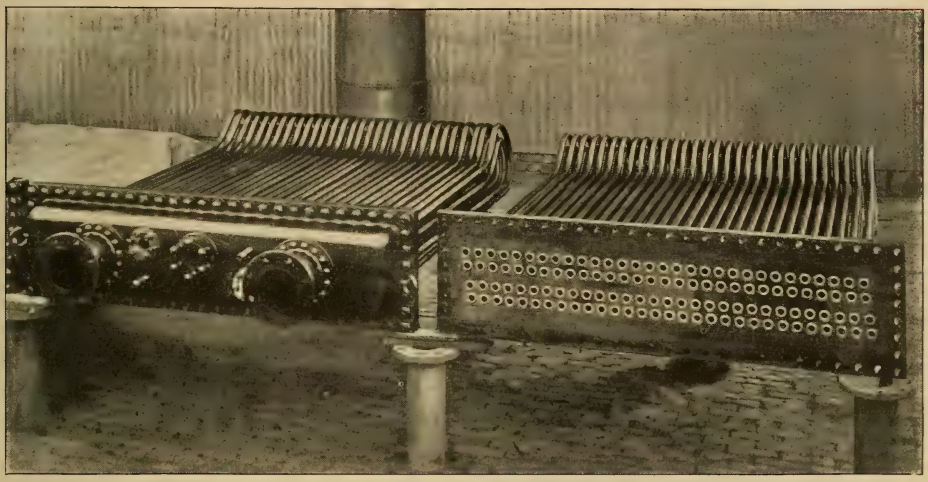


FIG 3.—TWO MC PHAIL & SIMPSONS SUPERHEATERS, ONE WITH DISH COVER BOLTED ON, AND THE OTHER WITH THE COVER REMOVED, SHOWING THE TUBE ENDS EXPANDED AND BEADED OVER. PROVISION IS MADE FOR CONNECTING A SAFETY VALVE AND BYE-PASS ARRANGEMENT, AND ALSO POCKETS FOR TAKING THE TEMPERATURE OF THE STEAM

flooding arrangements have been used, as a deal of scum and scale is carried into the tubes with the water, and if the flooding is frequently indulged in, the tubes, in time, get choked up, with the inevitable result that they burn out, thereby making the wear and tear an important item, as compared with the reduced coal bill. Again, it must not be forgotten that superheaters which are not furnished with a device for regulating the temperature become a source of trouble and expense if neglected.

The McPhail & Simpsons superheater has been designed with the express purpose of overcoming most of the disadvantages enumerated above, primarily by producing superheated steam at a controlled and constant temperature, and, further, by utilising more of the heat of the escaping gases than can be accomplished by ordinary economisers and feed heaters.

The apparatus shown in Fig. 1 consists of superheater tubes *T* connected together by top and bottom boxes *S*, which are divided into two compartments; connections to and from the superheater *C;* radiating pipes in the water space of the boiler *R;* and anti-priming pipe *A*.

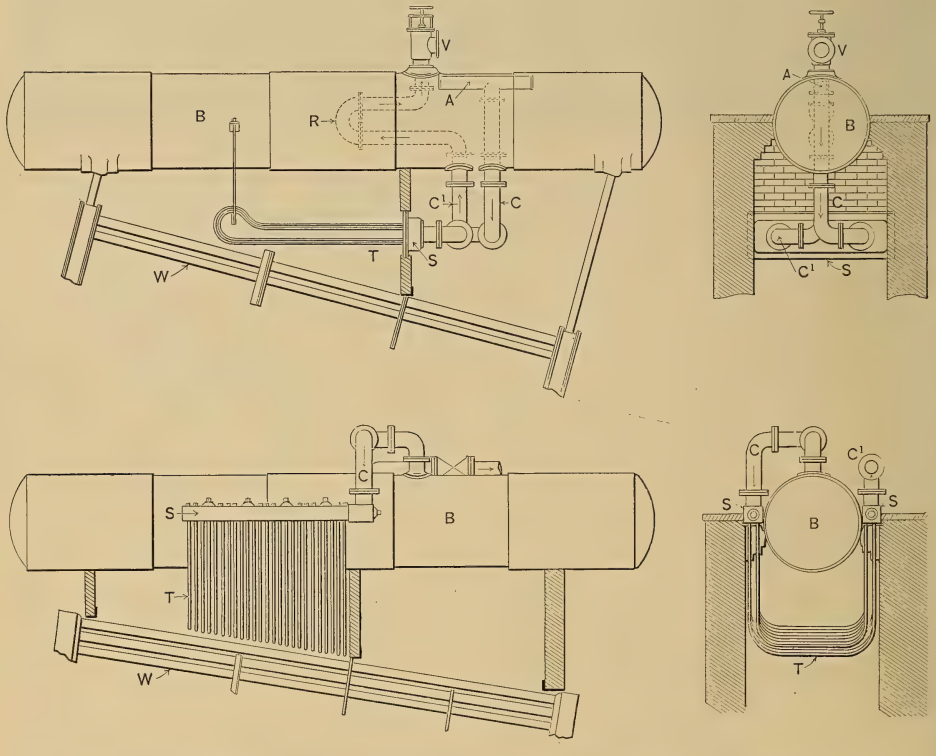
The steam passes from the anti-priming pipe *A* to the connecting pipes *C*, and thence through the first compartment of the top box and through the first nest of superheater tubes to the first compartment of the bottom box and into the radiating pipes *R*, which are placed in the water space of the boiler below the fire flues. It then passes out of the boiler again into the second compartment of the bottom box and up through the second nest of superheater tubes to the second compartment of the top box, and, by connections *C*, into the radiating pipes *R*, placed in the water space above the fire flues, and leaving the boiler at the stop valve.

It will be observed that the steam is superheated twice and carried into the boiler twice, where it gives up a part of its surcharged heat each time to the water in the boiler, thereby assisting evaporation, the steam leaving the stop valve at a controlled and constant temperature.

This apparatus is constructed of steel throughout. The superheater tubes are of cold, solid-drawn steel. The tube-plate is of rolled mild steel, 1¾ inches thick, and the boxes are of rolled mild steel plate, dished. It will also be observed that drain pipes are taken from the compartments of the bottom box so

that any water that accumulates in the bottom box may be drained off. Fig. 2 shows another form of the apparatus, the steam in this case being carried into the boiler only once.

The makers of the apparatus insist upon the importance of placing the superheater in the hottest part of the flue gases. In some other types of superheaters the apparatus is put in the gases after they have traversed the whole



FIGS. 4 AND 5.—TYPES OF SUPERHEATERS AS APPLIED TO WATER-TUBE BOILERS

length of the brickwork flues,—in fact, just before they pass up the chimney. Such an arrangement is considered to be faulty, from the fact that the rate at which heat is transferred from the external hot gases to the steam in the tubes is really proportional to the difference of temperature or to the thermal gradient between the gases and the steam.

The temperature of the gases on leaving the flue tubes will be in the neighbourhood of 1000° F., whereas just before passing up the chimney they will be only, say, at 500° F., the temperature of the steam itself being, say, 300° F.; hence, if the superheater be placed in the hottest gases it will receive

$$\frac{1000-300}{500-300}=\frac{700}{200}$$ or 3½ times as much

heat from the gases as if it were placed in the coolest gases. Those who prefer to put the superheater in the coolest place contend that by doing so they utilise only heat that would otherwise be wasted up the chimney, whereas if the superheater be placed in the hottest place, the gases are robbed of their heat and are thus prevented from doing as much evaporative duty in the side flues as they would otherwise be capable of doing. The reply to this is that practically the whole of the evaporation is done in the flue tubes themselves, before the gases reach the side flues and

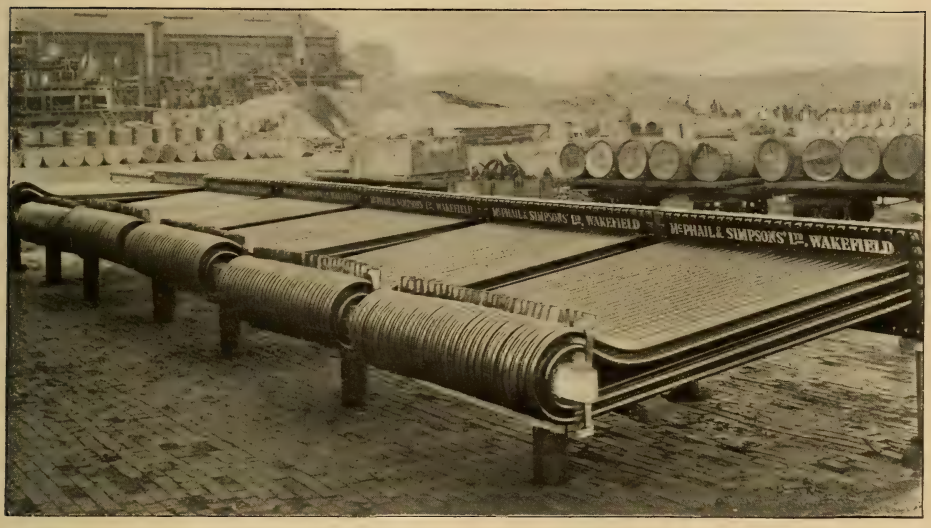


FIG. 6.—A BATTERY OF MC PHAIL & SIMPSONS SUPERHEATERS FOR THE CORPORATION OF BLACKBURN BOROUGH ELECTRICAL STATION

the side flue duty is little more than that of preventing radiation from the boiler.

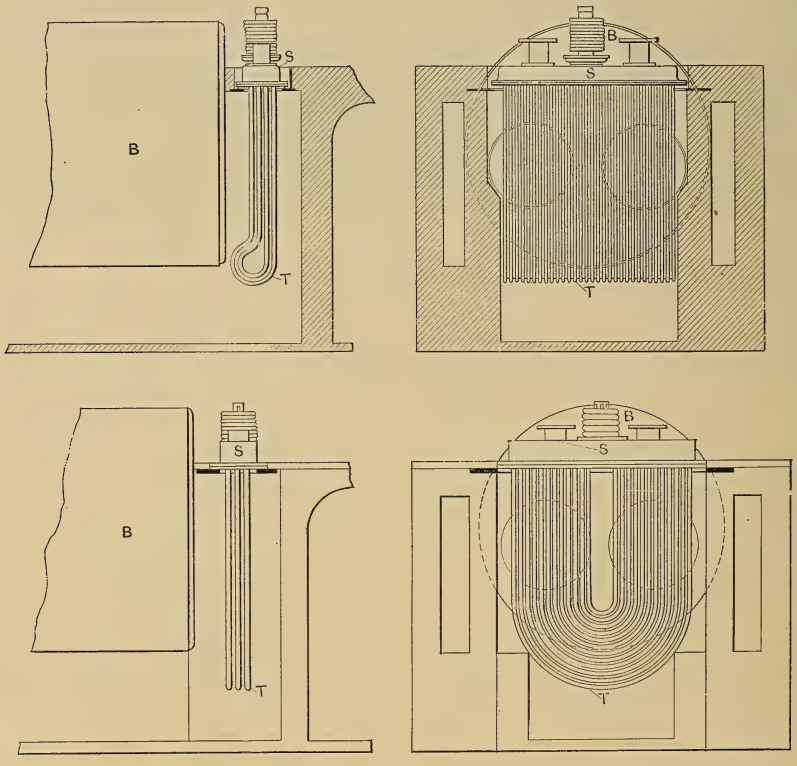
Whether readers will grant this point or not, they will, no doubt, admit that a great deal of the heat of the gases in the side flues is lost by radiation and conduction through the brickwork; hence it must be advantageous to catch as much as possible of the heat of the gases immediately after they leave the internal flues, for whatever else may happen, this heat, thus caught, is fully utilised in the McPhail apparatus, and none of it is lost by radiation or conduction before leaving the boiler. Some of it is utilised in evaporating water in the boiler itself and some is utilised in superheating the steam supplied to the engine, the exact proportion being determined by the ratio of the heat-receiving surfaces in the superheater and the absorbing surfaces of the radiators in the boiler.

By passing the superheated steam through the tubes in the water space, the superheat is reduced to any required degree and is kept tolerably constant at the predetermined amount. If, for any reason, the steam receives more superheat than usual in passing through the superheater, it gives up a corresponding larger amount of heat to the water in the boiler, and *vice versa*. In this way the temperature of the steam leaving this superheating arrangement remains fairly regular, and an excessive degree of superheat, which is so difficult to avoid under ordinary circumstances, is automatically prevented.

The degree of superheat is determined by the proportions between the heat-receiving and the heat-transmitting surfaces as explained above; if much superheat be required, only a small surface is exposed to the hot gases; if less be required, the area of the tubes in the water space has to be increased. From personal experience with the McPhail apparatus the writer is able to speak with confidence as to the constancy of the superheat when a boiler is working under normal conditions even under varying conditions of firing, quantity of steam passing, pressure, etc., and he knows of only one instance in which, under very abnormal conditions, the superheat was great enough to slightly damage the metallic gland packing. Apart from this one isolated case he has never heard of any trouble arising from this cause.

The question is often asked whether, when such a superheater as this is working conjointly with a boiler or battery

of boilers, an economiser or other form of feed water heater should be installed. In the writer's opinion it certainly should. The superheater utilises some of the heat of the furnace gases when their temperature is much higher than that of the saturated steam in the boiler, whereas a feed water heater utilises a further portion of the same heat when the gases are at too low a temperature to be economically used for evaporating or superheating purposes, and, indeed, it may easily reduce them to a temperature even lower than that of the steam in the boiler.



FIGS. 7 AND 8.—FORMS OF SUPERHEATERS WHERE HIGHLY SUPERHEATED STEAM IS REQUIRED

Objections are sometimes raised against superheaters being placed in the boiler flues, because they are alleged to impede the chimney draught. Such an objection has an imaginary value rather than a real one, for an ordinary water gauge is not sufficiently delicate to detect any difference in the draught before and after placing the superheater. Then, again, one occasionally hears complaints that this type of superheater is liable to give trouble through the collapsing of the internal pipes. That this was the case in a few of the early superheaters is not denied, but, thanks to better designs, coupled with excellent material and workmanship, this is an experience of the past, and even when such an accident did occur, it was largely due to negligence on the part of the boiler attendant.

Again, one hears of instances in which these superheaters have been installed and after some months have been removed because they have not come up to the guarantee of saving fifteen per cent. on the coal bill. It may be of interest to briefly examine one or two of such instances.

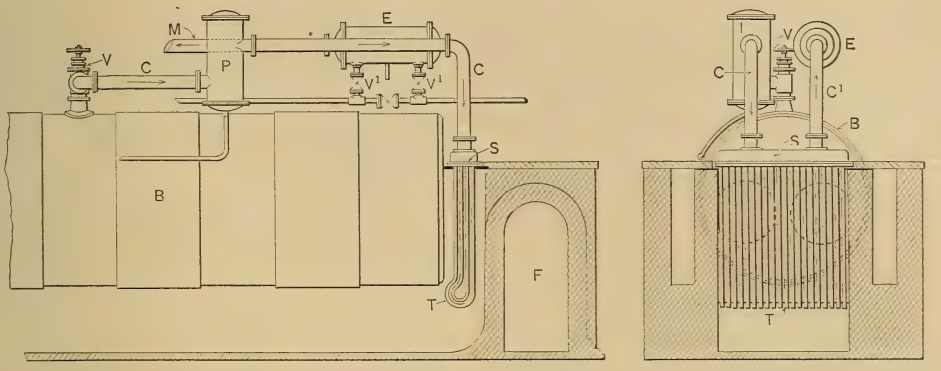


FIG. 9.—A SPECIAL FORM OF MCPHAIL & SIMPSONS SUPERHEATER

1.—*A* had five boilers. He was promised a saving of fifteen per cent. if he adopted this superheater, and, deciding to give the system a trial, had two of his five boilers fitted with superheaters. Prior to doing so, his books were carefully gone through and his expenditure on boiler coal was ascertained. After twelve months' working he complained that the guaranteed economy of fifteen per cent. had not been accomplished and his coal bill had been reduced by only nine per cent. He apparently did not, or would not, understand that the fifteen per cent. guarantee was for each boiler thus fitted, and that his nine per cent. saving with two-fifths of his boilers was in reality

$$\frac{9 \times 5}{2} = 22\tfrac{1}{2} \text{ per cent. saved per boiler}$$

thus fitted, or seven and a half per cent. above the guarantee. He appealed to law, but, needless to say, he had not a leg to stand upon and lost his case.

2.—*B* has his boilers fitted with superheaters, but his boiler attendants were too idle to sweep away the soot and ashes that were allowed to accumulate round the bottom of the superheater, and, of course, when they were thus buried they became practically useless. Accordingly, without taking the trouble to look into the matter he jumped at the conclusion that the apparatus was worthless. Then when the official test was made *with* the apparatus in use he had the fires drawn many hours before and took good care to have the brickwork flues cooled as much as possible; but, on the other hand, before the test was made *without* the apparatus, he fired up vigorously for many hours and got the brickwork nearly red-hot and the earth steaming for many feet around the boiler settings—probably in both instances without the slightest intention of fraud. In spite, however, of these adverse circumstances the saving amounted to about twelve per cent. This case was also taken into a law court, but immediately the judge and jury heard of the circumstances under which the tests were made, the result was a foregone conclusion and again the superheater triumphed.

Many similar cases have occurred, but all with one result when brought before an unbiased tribunal. A large number of careful tests have shown that the percentage of saving due to the apparatus may amount to as much as forty per cent. in plants which were previously doing badly, and to the writer's knowledge even plants that were previously considered to be very good have shown a saving of from ten to fifteen per cent. by the adoption of this form of superheater.

In the case in which a steam engine is situated at some distance from the superheater, much of the superheat will disappear through radiation before the steam reaches the engine, however well the pipes may be covered. The function of the superheater in such a

case is to supply dry, or slightly superheated, steam to an engine situated at a considerable distance from the boiler, which, under ordinary circumstances, would probably be flooded with wet steam.

Figs. 4 and 5 show types of superheaters as applied to water-tube boilers, the working of which will be easily understood on reference to the illustrations.

Those who have had experience with such boilers know how great is the need of some such appliance for drying and superheating the steam. Especially is this the case when the boilers have to be worked beyond their normal steaming capacity. At one of the electric stations alone, which has come under the writer's notice, sixty of the superheaters as just described are working successfully.

Recently a simpler and cheaper form of superheater has also been put on the market by McPhail & Simpsons which requires no alterations of any kind whatever to the boiler itself. It is simply a series of bent tubes, with suitable boxes through which the whole of the steam passes on its way from the boiler to the engine, or to be otherwise utilised, the outside of the tubes being exposed to the hot escaping gases. This type of superheater is shown in Figs. 7 and 8, and is a very suitable one in cases where highly superheated steam is required.

In a special form of the McPhail superheater, shown in Fig. 9, the steam is taken from the stop valve and passes through a catchall *P*, where the froth or scum, which in most cases is carried over by the priming water when the boiler may be forced, is intercepted as the steam passes to the superheater *S*. In the case of bad water this scum, if not intercepted, may have a very deleterious effect on the tubes, especially if the apparatus be neglected, as is often the case.

When the steam passes through the superheater and is returning to the main steam pipe, it passes through a modifier *E*, in which the high temperature of the superheated steam is reduced, and issues therefrom at a controlled and constant temperature. This is accomplished by passing the whole, or a part, of the feed water through the modifier, the amount being determined by regulating the valves *V' V'*, either before or after the feed has passed through the ordinary feed water heater. Inside the modifier there is a coil through which the feed water circulates; the highly superheated steam surrounds the coils and thereby has its superheat reduced to any desired extent. This apparatus is supplied with or without either or both the modifier and catchall.

The modifier, as described above, is of special interest to users of superheaters who may not have adopted the McPhail & Simpsons system, as it can be easily applied to existing superheaters at small cost, and ensures the supply of steam at a constant amount of superheat at a given pressure, which is the very crux of the superheating problem that is engaging so many of the engineers of to-day. This modifier is very effective in its working, requires no attention, and is applicable to all types of superheaters.

THE APARTMENT HOTEL IN NEW YORK

SOME OF ITS ENGINEERING PROBLEMS AND THEIR SOLUTION

By Reginald Pelham Bolton

THE demand among the well-to-do class of residents in the city of New York for the conveniences of a hotel without the annoyances of association with promiscuous guests has been largely increasing in recent years, and the development of such buildings has continued to follow the requirements. The increasing difficulties of management of servants is one strong incentive to people of means to adopt a class of residence in which the control of all domestic service is on other shoulders, and in which, also, they can entertain in a style commensurate with their means without the anxieties of preparation.

The increasingly migratory habit of New York society has further contributed to the popularity of this class of residence, since apartments may not only be closed for the seasons of the tenants' absence, but, during that absence, may be properly cleaned and maintained without the private engagement of help for the purpose. The competition between localities and buildings has led to the introduction of many other conveniences tending to facilitate domestic necessities, and rendering the comparative total cost of residence in equal style in a private home probably greater than that of the charge of an apartment hotel, apart from the absence of trouble and annoyance. There still exists, however, a certain class of residents whose tastes require greater privacy, particularly in the matter of meals, than is obtainable by the usual hotel system of public or semi-public accommodation. For this class of tenants, who, nevertheless, desire the general advantages of the hotel, private kitchen accommodations must be provided, sufficient for their private purposes, and supplemented by the conveniences of the hotel kitchen in the entertainment of guests. These various dispositions of tenants are now pretty well settled, and in the latest and largest of these buildings an attempt has been made to provide such accommodations as will meet all the existing requirements under one roof. While the financial success of such an attempt is still undetermined, the features of the conveniences provided and the problems entering into their provision are of interest, particularly as illustrating the increasing demands upon engineering skill and materials for their provision and operation.

An apartment hotel of the largest present dimensions, recently completed, has been arranged to house from 1200 to 1400 resident tenants in 340 suites, as planned on paper, the number being liable to vary by combining or dividing suites to meet individual wishes. The building occupies an entire block front, and is of equal average depth. Its height is 200 feet, within which are arranged sixteen floors and an attic floor, these being of varying heights, proportioned, as is often the case, not to meet any special need of light or air, but to suit the exterior architectural decorative features. Light and air being an element of prime importance, the present practice of exterior courts is followed, whereby the exterior surface of the building is increased from the outside dimensions of the plot by a length of 550 feet additional. A photographic reproduction of this hotel, known as the "Ansonia," appears on the following page.

The elementary question of the form and location of corridors, stairs, and elevators being very desirably settled in

THE "ANSONIA," THE LARGEST AND BEST EQUIPPED APARTMENT HOTEL IN NEW YORK. THERE ARE SEVENTEEN STORIES ABOVE THE STREET LEVEL AND TWO BELOW. HEIGHT FROM STREET TO ROOF, 199 FEET. THERE ARE 340 SUITES, COMPRISING 1600 ROOMS AND 345 BATH ROOMS

the form of a large letter **H**, the disposition of rooms becomes a matter of detail planning, which is, unfortunately for the engineer, in these days of haste in construction, subject to much liability to rearrangement, or, from his point of view, disarrangement, after construction is under way.

The smallest possible amount of space between the ceilings of one story and the floor level above is naturally a desideratum to owners, as every inch thus buried is valueless from the point of view of the tenant. Therefore, the problem of extending under floors the innumerable lines of piping which now go to form the conveniences of a building of this character is an increasing one, and is the main source of architectural difficulty and one of the chief reasons why special engineering skill is called for, and by which much of the appearance, as well as the success, of the building is to be decided. In order to illustrate the point the following statistics of this large building may be of interest:–

PIPING ACTUALLY INSTALLED AND PRACTICALLY ENTIRELY CONCEALED FROM SIGHT, YET ACCESSIBLE AT VITAL POINTS

Character	Sizes	Feet	Totals	Miles
Sanitary Work				
Vertical soil and waste pipes	4 in. to 5 in.	55,585		
Branch vents	1½ in. to 2 in.	21,418		
Horizontal drainage	4 in. to 10 in.	3,503		
Cellar and kitchen drainage	4 in. to 5 in.	3,000		
			83,506	15.81
Water System				
Main connections	4 in. to 6 in.	3,465		
Hot, cold and circulation risers	¾ in. to 3 in.	138,630		
Branch connections	½ in. to 2 in.	67,661		
Water closet supply	3 in. to 5 in.	22,680		
			232,406	44.01
Fire System				
Risers	4 in. to 6 in.	2,340		
Hose	2½ in.	8,810		
			11,150	2.11
Gas				
Mains	3 in. to 4 in.	1,740		
Risers	2 in.	7,260		
Branch	½ in. to 1½ in.	187,967		
			196,967	37.30
Hydraulic Elevators				
Water piping	4 in. to 12 in.	3,800		
Cylinders and plungers	4 in. to 12 in.	6,750		
			10,550	1.99
Steam				
Power and heating	½ in. to 16 in.	95,000		
Cooking, etc		3,000		
			98,000	18.56
Refrigeration				
Brine circulation	½ in. to 8 in.	7,373		
Condensers	1 in. to 1½ in.	6,060		
Iced water	¾ in. to 4 in.	4,296		
			17,729	3.35
Pneumatic				
Brass despatch	3 in.	3,680		
Air		1,980		
			5,660	1.07
Electric Conduit				
Risers	1¼ in. to 2 in.	22,050		
Branches	½ in.	185,385		
			207,435	39.28
Bells				
Conduit	⅜ in. to 1 in.		28,700	5.43
Gas Flues				
Earthenware	4 in. to 10 in.		13,300	2.53
Vent and Fresh Air Ducts			11 000	2.08
			916,495	173.57

Connected with the above are installed, approximately, 71 tons of drainage pipe fittings from 1½ inches to 10 inches; 26 tons of water pipe fittings from ½ inch to 8 inches; 70 tons of steam pipe fittings; 7 tons of heavy hydraulic fittings; 9 tons of refrigerating pipe fittings; and about 6 tons electric and miscellaneous fittings, making a total of 189 tons.

These are controlled by the following valves, which, by careful foresight, must be accessibly located throughout:—

5,586	On Croton branches	½ to ¾ in.
2,706	On Croton supplies	1¼ to 2 in.
461	Gate valves	4 in.
167	Gate valves	5 in.
26	Gate valves	6 in.
3,766	Faucets on fixtures	½ to ¾ in.
729	Steam valves from	1½ to 12 in.
2,071	Radiator valves	¾ to 1½ in.
2,071	Thermostatic valves	½ in.
296	Brine pipe valves	½ to 3 in.
1,133	Gas valves	½ in.
200	Fire valves	
19,212	Approximate total of valves.	

There are provided 2440 sanitary fixtures and 43 rain water leaders. The water system includes 4 water filters capable of filtering 3200 gallons per hour, stored in tanks of 22,000 gallons capacity in the cellar and 26,000 gallons on the roof; also 165.700 gallons in a swimming pool. Seven pumps handle the above, with a capacity of 2000 gallons per minute for fire purposes.

The fire-fighting system is elaborate. The house and fire pumps, uniting with six engines in the street, can pump to a fire at once through four multiple-pressure drums. There are 84 fire-hose outlets, each equipped with valve, reel, and hose, aggregating 8810 feet of fire hose.

There are 2100 gas outlets in all, 1011 gas-log fireplaces, and 122 gas ranges, requiring, under ordinary systems, 268 chimney flues, reduced by design of the

author to 72, of a total length of 13,392 feet of flue, the gases being drawn off by roof vent fans to which they are connected.

Some further statistics are,—7849 electric outlets, providing for about 19,000 electric lamps, equivalent to 204,000 candles, and fed by a network of 83 miles of copper wire; and nearly 1200 bells, requiring 40 miles of bell wire.

There are 2071 steam-heated radiators, controlled by 4142 valves, and presenting about 100,000 square feet of heating surface. Eleven out of the sixteen electric motors, comprising 119 out of 141 horse power, operate fans for ventilating purposes. Vent flues, amounting to about a mile in combined length, supply 108,000 cubic feet of fresh air per minute to the building, and 190,000 cubic feet of foul air are withdrawn from the kitchens, toilets, and machinery and other spaces.

There are 120 private kitchens, each with a gas-range, and also with provision for electric cooking, if preferred. With these kitchens there are 120 private refrigerators, with gross contents of 1862 cubic feet of interior space, besides 9676 cubic feet in the two restaurant kitchens. Iced water is supplied by 147 fountains, providing 1800 gallons of drinking water per hour, the whole operated by a plant of a capacity equal to making 36 tons of ice every twenty-four hours.

The floors are made accessible from the street, and the passengers, servants and various goods are hauled by 17 hydraulic plunger elevators, operated by plungers descending into cylinders sunk into the solid rock, requiring holes of 3400 feet total depth, bored from 10 to 14 inches in diameter, and 3557 feet of screwed steel tubes for polished plunger rods, giving a travel of 3384 feet if all cars were lifted at once, or 1¼ miles in one round trip, bottom to top and return, and an average travel of 19 miles per hour, operated by pumps of 3400 gallons per minute capacity, under a pressure of 160 pounds per square inch. The cars would carry, without crowding, 176 persons each trip, so that the building could be completely emptied in ten minutes.

Power is supplied for all these services by four boilers, aggregating 1480 horsepower; five electric generators, of a total capacity of 1050 kilowatts, operated by engines of 1760 indicated horse power. In conjunction with these there are twenty-five pumps in all, mostly compounded, and four steam ejectors.

The special conveniences include a laundry, with a capacity of 25,000 pieces per day, and a shirt, collar, and cuff plant of 1200 pieces; also a separate disinfecting washing plant, so arranged that infected clothing may be brought from any floor in a screwed closed can and subjected to high steam pressure in a special washing machine.

This laundry is arranged with a separate entrance from the street, for outside employees, and has spaces for sorting, mending, and checking. It is also provided with a chamber having a locked drying closet for the use of tenants who do their own washing, and may have the use of a locked compartment one day a week. A special reduced temperature is provided for this closet, so that clothes left in it for a long period cannot be scorched. The provision of this convenience contributes to the appearance of the building, precluding any excuse for drying articles, such as handkerchiefs, out of windows.

Provision is made for storing baggage and surplus articles, of which a large amount is apt to accumulate. Room for 110 baby carriages has to be provided, an average of one to each three suites, and means to produce them promptly when required. Trunks average three per suite, or over a thousand to be cared for, besides innumerable small packages and articles, such as bird and parrot cages.

As tenants are constantly requiring the removal of doors in summer and their replacement in winter, room has to be provided for about 300 such articles. A carpenter's shop, with a power band-saw and general joiner, may be kept occupied the year round in fixing shelves, repairing furniture, making alterations to suit tenants, and in general repairing.

One man's entire time is expected to be occupied in keeping up the sanitary system, watching traps and clean-outs, clearing the leaders from soot, and doing other similar work. The beating of carpets is still done on the roofs of these buildings, but will, it is hoped, ere long be dispensed with in favour of the new system of cleaning in place by suction. Provision is, therefore, made for the installation of necessary piping and hoses when the system shall become perfected. The need for such a development may be gathered by the fact that the apartment floor corridors alone aggregate 8160 feet in length, and with three widths of carpet, one yard wide, require over 8000 square yards to be cleaned.

About 240 employees are required, including managers, clerks, kitchen, laundry, and general chambermaid help, waiters, bell boys, elevator runners and messengers. The telephone system comprises 365 stations, and is made a branch exchange of the public system, with two attendants and three public booths. Tenants in all well-appointed houses now have the public and interior service free. The manager's office is the centre of all authority and control, and, therefore, all time-saving devices centre at it, and the author has made it a practice to equip it with the utmost detail.

From it radiate all pneumatic message and package tubes to all floors; bell calls from every apartment; several telephones to the exchange; fire calls from every floor and fire station and a special system of fire-alarm gongs which can be separately or unitedly operated. In addition, on a large panel, are arranged instruments recording the steam pressure on boilers and the electrical pressure; other gauges show the pressures of house-heating and vacuum returns, brine, water supplies, elevator water pressure, and gas, with thermometers and gauges on the ventilating air supply, so that a failure of or shortcoming in any element can be instantly detected and complaints avoided by prompt action.

It is customary to utilise street frontages by renting off spaces as shops, and judgment is sometimes shown in the selection of such as will contribute to the tenants' convenience, interior access then being afforded. Thus, a bank with a safe deposit vault system and cold storage for furs is one of the features of the house described; and a drug store, with a soda fountain, a florist's shop adjoining the public dining-room, bookstall, cigar shop, and telegraph and cable booth, are all desirable additions. It is common to provide for a physician's suite, and in this case also for a dentist, such professionals readily acquiring quite a practice within the walls of their own residence.

Milk is a material in universal demand, and a population of 1800 souls warrants the provision of a separate milk store and distributing centre, with cold storage capacity and means to wash bottles and to handle cans.

Automobiles are the present fad of the well-to-do, and while not anticipating that they will be as widespread a means of amusement as at present, space has to be provided for the storage of a certain number, and in this case a "garage" is arranged in the sub-basement for twenty-four vehicles of all sizes, with a chamber with lockers for chauffeurs, and a system of recharging for electrically-operated machines, hose for washing, and an engineer's repair shop, with an outfit of machine tools and a hoist to lift the automobiles when under repair. The carriages can be conveyed to the rear courtyard by a large elevator, 20 feet long and 12 feet wide on its platform, which is also utilised to carry furniture waggons to the sub-basement where they may be loaded direct into the largest of the freight elevators.

The general conveniences also include a barber's shop with eight chairs in the basement, with manicure parlours and bootblack stand. The swimming bath is not completed, but is excavated and lined for a length of 100 feet, a width of 32 feet, and a depth of 10 feet. Spaces around it have been planned out and provided with various accessories in the rough, such as waste pipes, etc., for dressing rooms for men and women, shower baths, Russian baths, complete

Turkish bath and plunge, also towel and dress room near the laundry, observation gallery, diving boards and gallery, and a large club room or café overlooking the pool.

The attic is divided off into sections for the sleeping rooms of male and female help, with special rooms for extra servants of tenants who can be called by special bell or telephone connections from these rooms. There are two studio apartment suites on this floor, and special spaces for sorting house linen, storing blankets, and for cleaning garments with electric irons and washing apparatus.

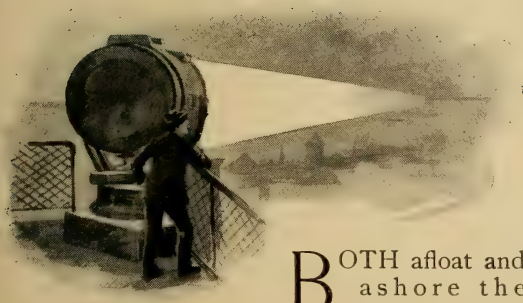
In every one and all of these matters, and a vast number of uninteresting, but equally important, details, the mechanical engineer is required to act, and upon him devolve to a great extent the due proportions of services not only mechanical, but personal. It is he who decides the extent and quality of the personnel of the service, and, as in this extremely large instance, the entire designing of the service floors and their divisions and appurtenances, comprising the entire basement, sub-basement, and attic floors, is his work. He can, and does, by his ingenuity and forethought, avoid the disfigurement of the building by unfortunate excrescences, such as pipes and roof houses, and upon his judgment and experience the comfort and convenience of the building are mainly dependent, while under his direct design comes an expenditure of not less than one-fifth of the entire cost of the building.

It seems somewhat unfair, then, that the credit of such buildings should, for lack of knowledge of these important elements, be generally ascribed to the architectural profession on the merit or demerit of their outside elevation, or their inside, but still visible, arrangements, or, as one would say of persons, "on their face," apart from their interior qualifications or mental capacity.

ELECTRIC SEARCHLIGHTS

THEIR USE AFLOAT AND ASHORE

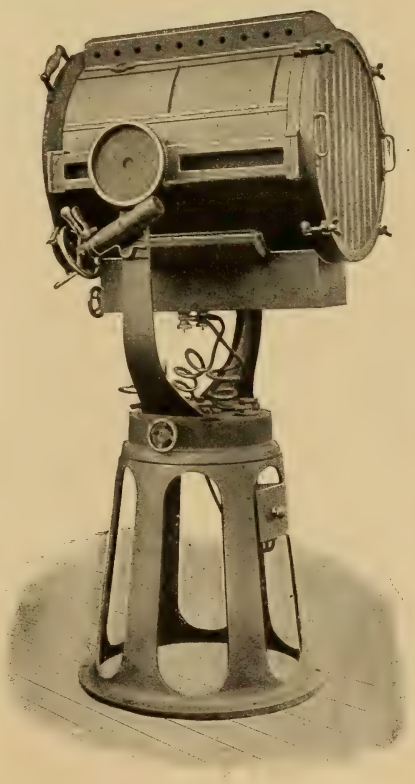
By Frank C. Perkins



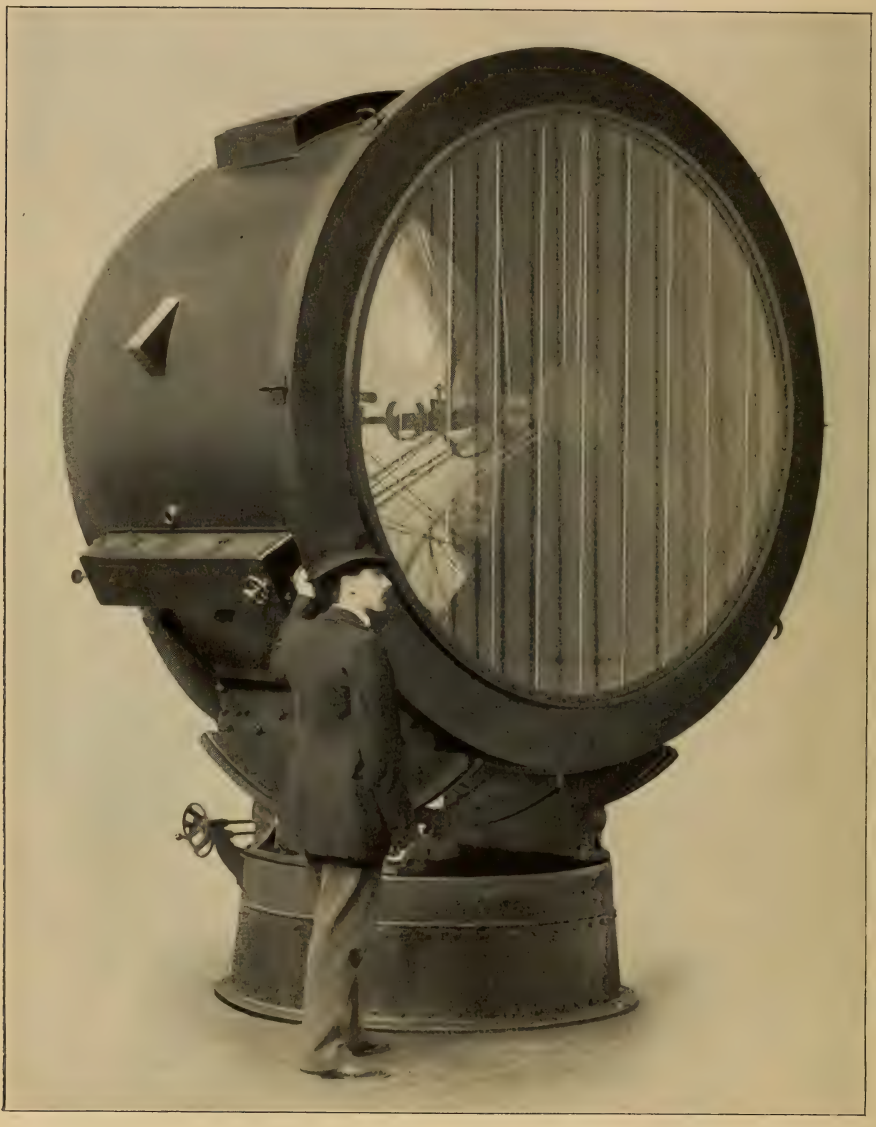
BOTH afloat and ashore the electric searchlight is to-day of the greatest importance, the merchant marine finding this apparatus almost as indispensable as the main engines and steering gear of the ship. Some of the portable projectors used for military purposes are provided with raising and lowering devices upon the waggon on which they are mounted, so that the projector may be raised for service and lowered for transportation. The illustration on page 38 shows this form of searchlight of German construction, made by Messrs. Schuckert & Co., of Nürnberg. The electric cables which carry the necessary current for the lights are coiled upon reels mounted upon carts ready for use when desired.

Another searchlight for land purposes, constructed by the same firm, has a total diameter of 2000 millimeters, and projects a beam of light of 316,000,000 candle power. This projector is operated entirely by means of electric motors, one of which turns the searchlight upon a horizontal axis, and the other vertically, the operator being required simply to move the handle of the controller in the direction he wishes the beam of light to pass.

For use in lighthouses a new form of combination searchlight has been designed and constructed in Berlin, Germany. This throws three beams of light at the same time from the top of the tower, as seen in the view on page 35. This Siemens-Schuckert searchlight has three arc lights, reflecting mirrors, and projector regulating devices 120 degrees apart, all operated automatically. The



A NAVY STANDARD PROJECTOR, MADE BY THE CARLISLE & FINCH CO., CINCINNATI, OHIO, U. S. A. THESE PROJECTORS ARE MADE IN ACCORDANCE WITH THE SPECIFICATIONS OF THE U. S. NAVY, AND HAVE BEEN APPROVED BY THE BUREAU OF EQUIPMENT



SEARCHLIGHT WITH ELECTRIC MOTOR CONTROL, MADE BY MESSRS. SCHUCKERT & CO., NÜRNBERG, GERMANY. 316 MILLION CANDLE-POWER; 80 INCHES DIAMETER

carbons of the arc lamps are fed automatically, and electric motors are used for turning the three searchlights, while a fourth searchlight is mounted upon the top, this working entirely independently of the other three, and moving in any direction desired. This new form of electric flashlight has been installed in the lighthouse tower at Heligoland.

The three searchlights mounted on the lower revolving platform 120 degrees apart have mirrors 29 inches in diameter and utilise a direct current of 34 ampères each, the platform revolving at the rate of four revolutions per minute. The current is supplied to the tower lights by a lead, iron-armoured, covered cable connected with the power station. The power plant consists of two steam engines directly connected to dynamos of

216 ampères capacity at a pressure of 75 volts.

This new electric beacon is to take the place of the old petroleum light that so long flashed out its danger signals at the mouth of the river Elbe. The new electric light is probably the most powerful at present in operation.

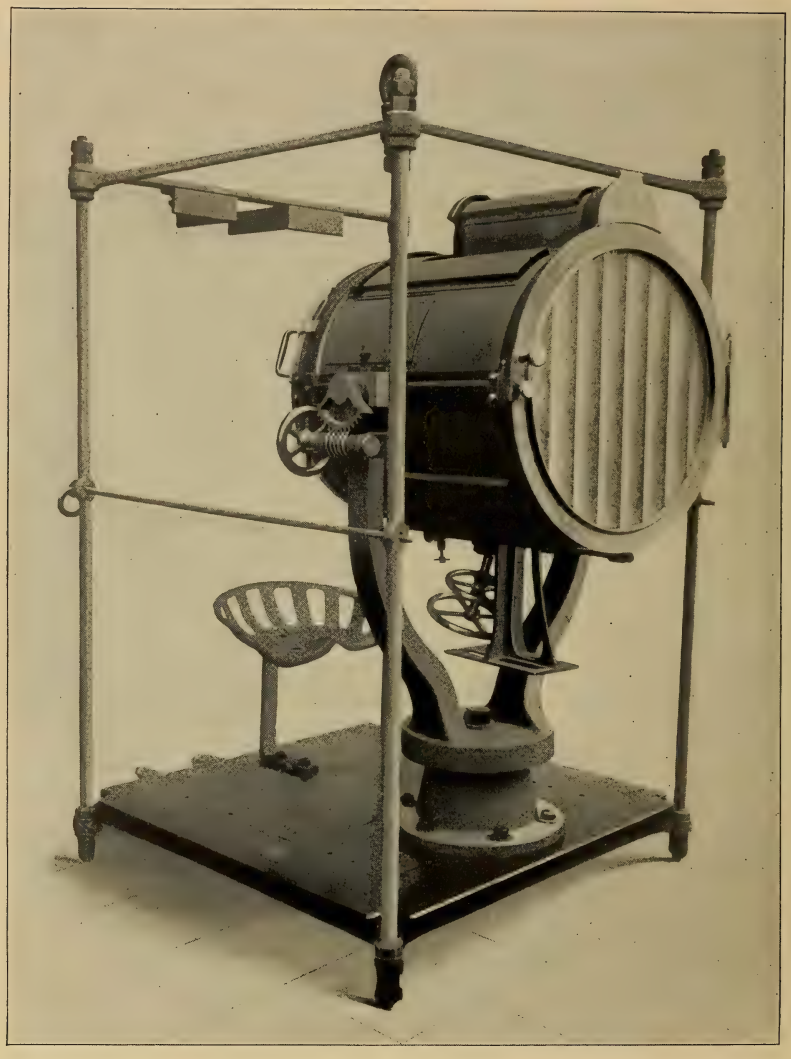
Some of the foreign searchlights of the Schuckert type are designed with so-called "Iris" diaphragms, the leaves of which slide within a fixed diaphragm located in the axis of the ray of light. This shutter is provided in order to make the projector perfectly light-tight at any moment desired. While most of the larger electric lamps are constructed both in this country and abroad for automatic working, they can also be adjusted by hand. With a normal current intensity of 120 ampères, the intensity of the rays emitted from the mirror is of more than 60,000,000 candle-power, irrespective of the absorption of the atmosphere. Objects the size of a man can be distinctly observed within an operating circuit amounting to about two miles.

In order to convert concentrated light rapidly into diffused light an apparatus is used in German searchlights known as a "double disperser." This apparatus is composed of two parallel systems of cylindrical lenses which may be slid against one another, whereby the angle of dispersion of the light can be varied, if desired, within the limits of from 2 degrees to 45 degrees. On account of the exterior lenses having a shorter focal length than the interior ones, there are formed between the emitted rays dark spaces, within which the wings of a signalling apparatus can be provided for, without intercepting useful light.

The searchlight projector shown on the next page arranged upon a movable

GERMAN TRIPLE-BEAM SEARCHLIGHT FOR LIGHTHOUSE SERVICE

cage, is designed to be hauled to the topmast of a large vessel, and the beam of light may be projected in any direction desired. These electric projectors are usually operated by hand,



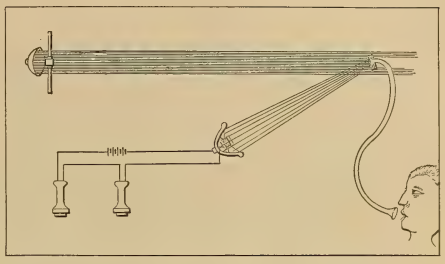
A SEARCHLIGHT PROJECTOR MOUNTED IN A CAGE SO THAT IT CAN BE RAISED ON A SHIP'S MAST, FOR EXAMPLE. THE PROJECTOR IS CONTROLLED BY AN OPERATOR SEATED IN THE CAGE, BEHIND. MADE BY MESSRS. J. H. HOLMES & CO., NEWCASTLE-ON-TYNE, ENGLAND

the operator being provided with a seat in the cage.

The United States Government searchlights of less than 13 inches diameter are fitted with Mangin ground glass, silver-plated mirrors, which have two spherical surfaces of different radii, and the reflection and the refraction of the glass cause the rays of light to be projected in a parallel beam when the arc is in the focus. The United States Government projectors of larger sizes are arranged with parabolic ground glass, silver-plated mirrors with true parabolic surfaces. These are specified by the Navy Department, as the quality of the light from the parabolic mirror is whiter, and consequently is claimed to be more penetrating.

Electrically-controlled projectors may be operated from a distance, a good example of such a projector being illus-

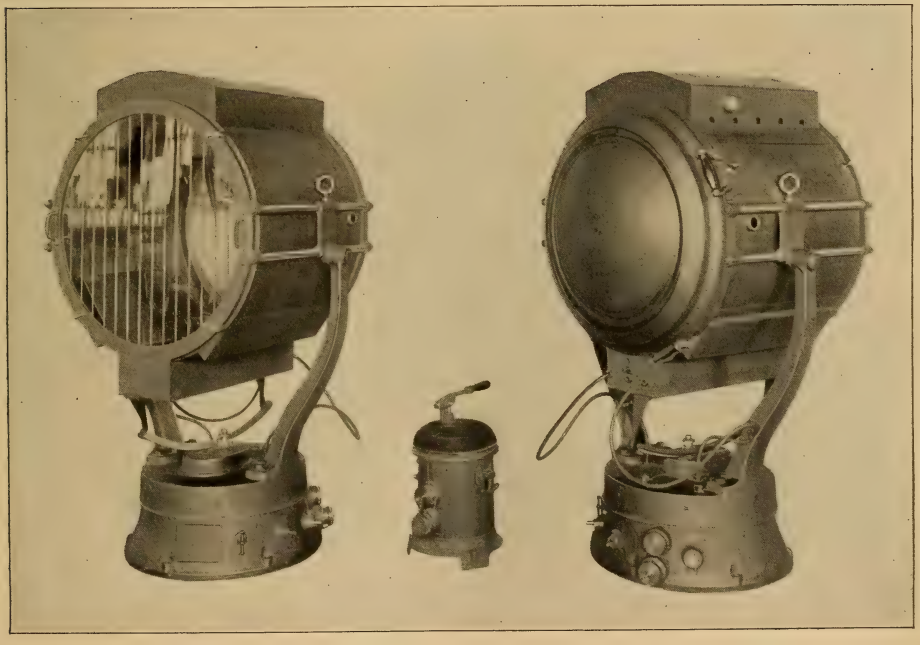
trated on this page, this one being made by the General Electric Company, of Schenectady, New York. The controller in this case differs from that of the German searchlight shown on page 34 in that all of the movements of the beam of light are controlled by a single handle. By raising or lowering the handle or moving it to the right or the left the current is caused to operate two electric motors in the base of the searchlight, and when the handle of the controller is released it is brought back automatically to the neutral position, holding the projector locked in position. One of the motors operates a train of gears controlling the vertical movement and the other is connected with a train of gears controlling the horizontal movement of the beam of light. The lamps have horizontal carbons, and are designed to throw the greatest possible amount of light on the reflector, and screen shutters are provided to prevent the direct rays from leaving the projector, so that all of the rays of light are reflected and sent out parallel. The



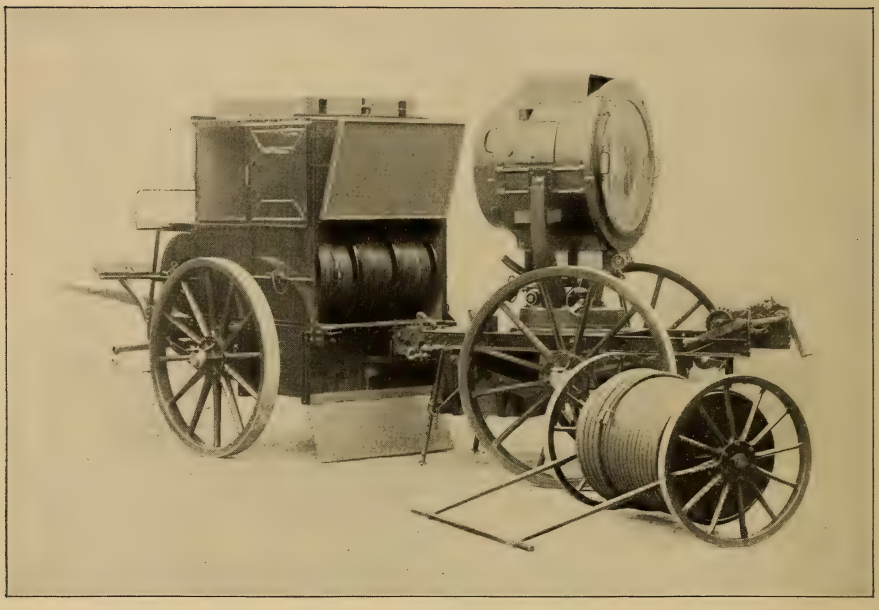
PROFESSOR BELL'S RADIOPHONE

positive and negative carbons in all forms of searchlights are usually fed automatically, especially in the larger sizes, and are so proportioned that the arc remains in the focus of the mirror until the carbons are entirely consumed.

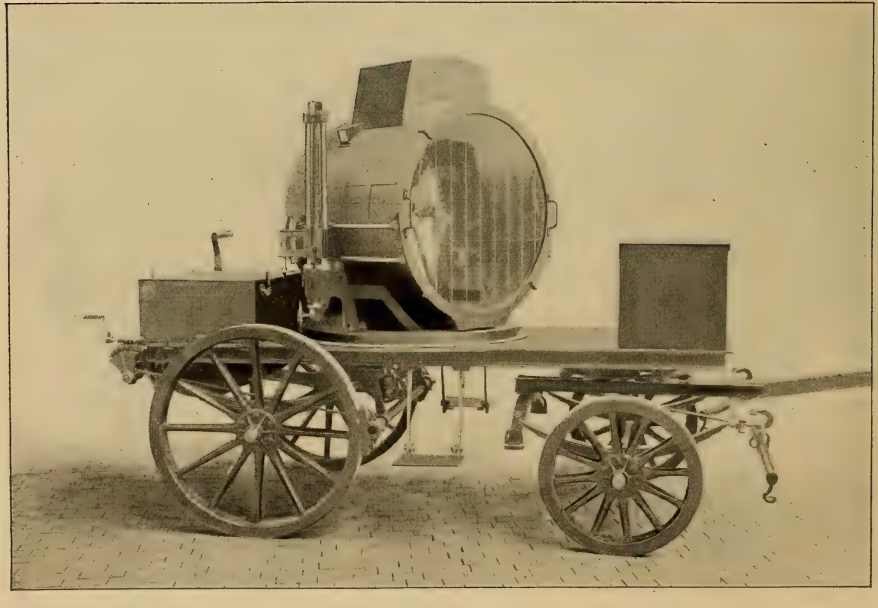
The American types of pilot-house searchlights are mounted upon the top of the pilot-house and are operated from within. The projector may be locked at any desired angle by turning the handle of the lever, so that it screws against the quadrant below like a set screw. Both vertical and horizontal movements of the beam of light are accomplished



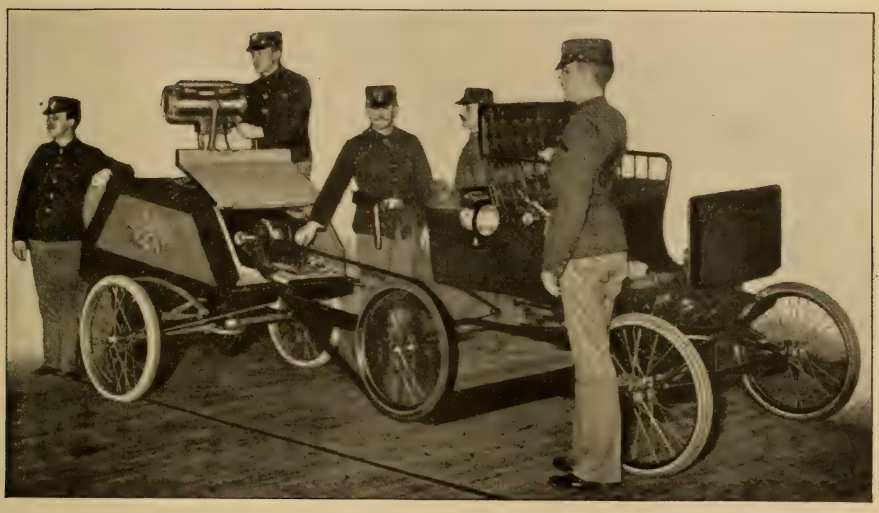
THIRTY-INCH NAVAL SEARCHLIGHT PROJECTORS WITH ELECTRIC MOTOR CONTROL, MADE BY THE GENERAL ELECTRIC CO., SCHENECTADY, N. Y.



A MILITARY SEARCHLIGHT OUTFIT BY MESSRS. SCHUCKERT & CO., NÜRNBERG, GERMANY



A SEARCHLIGHT PROJECTOR WITH RAISING AND LOWERING DEVICE. THE PROJECTOR IS HERE SHOWN LOWERED, FOR EASE IN TRANSPORTATION. ALSO MADE BY MESSRS. SCHUCKERT & CO.



A 7-INCH MANGIN MIRROR PROJECTOR MOUNTED ON AN AUTOMOBILE CARRIAGE FOR MILITARY USE. MADE BY CHARLES J. BOGUE, NEW YORK

by means of the same lever, which is located within easy reach of the pilot.

It is not uninteresting here to note the fact that by the invention of Ernst Ruhmer, a German physicist, in connection with his selenium cell, it is possible to telephone over a beam of light from a naval projector without any difficulty whatever. In this way merchant vessels or warships may be in telephonic communication when within a distance of several miles of one another. The method of operation of this form of space telephony is as follows:—

Selenium is a metal which varies in resistance according as it remains in the dark or is exposed to light. This property of selenium is taken advantage of in searchlight space telephony by employing a battery and transmitter, superimposing waves on the arc light circuit. The beam of light which is reflected to the distant point by the searchlight is received by a parabolic reflector, in the focus of which is placed a selenium cell connected with a battery and a pair of sensitive telephone receivers.

By means of the searchlight and the Ruhmer selenium telephone apparatus messages have been sent several miles from an experimental station near Berlin, and extensive work in this line is to be carried on by the German Government in connection with the imperial fleet in the Baltic Sea.

The diagram on page 37 shows the connections of Prof. Alexander Graham Bell's radiophone, as described by Mr. W. J. Hammer in a paper on "Selenium" recently read before the American Institute of Electrical Engineers. Professor Bell, about twenty years ago, made some interesting experiments with his radiophone, in which a mica or glass diaphragm, covered with a silvered foil, was used to reflect a powerful beam of light upon a selenium cell placed in the focus of a silvered reflector. To the selenium cell were connected a pair of telephones and a battery. At the back of the silvered diaphragm was a flexible tube and mouth piece into which words were spoken. The sound waves causing the diaphragm to vibrate, sent pulsations of the reflected light upon a selenium cell, producing corresponding vibrations in its resistance and reproducing audible sounds in the telephone. Professor Bell used this over only very short distances, while the new German apparatus makes space telephony possible over distances of nine or ten miles by the use of powerful searchlights.

LOCOMOTIVE BUILDING IN GERMANY

By A. von Borries

IT is only since the Paris Exposition of 1900 that locomotive building as practised in Germany has been properly brought to the attention of Great Britain and the United States. What was shown at Paris in that year testified splendidly to the excellence of both design and construction of locomotives turned out by German establishments.

There are in all thirteen works given up to their manufacture. Some of them have a capacity of as many as 300 engines a year. The railways, which are nearly all owned by the Government, do not build their locomotives, but simply repair them as occasion requires, and are united under one system, with uniform standards for permanent way, rolling stock, and other equipment, all of which works in favour of the German locomotive builder whose output, under this system, is made up of a large number of standard parts.

At present the combined capacities of the several works are considerably more than equal to German demand alone, and the result has naturally been a reaching-out for foreign business, of which a most satisfactory volume has been developed.

Up to the year 1890 nearly all the German, and, in fact, most of the Continental, railways used six-wheeled engines for all kinds of traffic. Passenger engines had four-coupled wheels, and goods engines were six-coupled, and their weights ranged from 36 to 42 tons. Leading trucks with short wheel bases were used only by some of the southern roads. Eight-coupled engines were employed in exceptional cases on a few lines with very heavy grades.

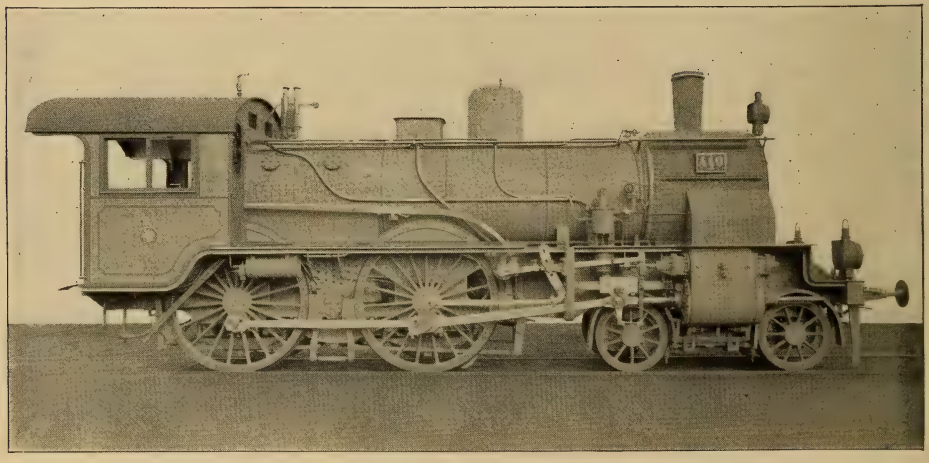


FIG. 1.—A TWO-CYLINDER COMPOUND PASSENGER LOCOMOTIVE BUILT BY A. BORSIG, OF BERLIN

Since 1890, however, the growing traffic requirements of the country have exceeded the capacities of these locomotives. More powerful engines have, therefore, gradually been put into service,—four-coupled, eight-wheel engines of "American" pattern for express

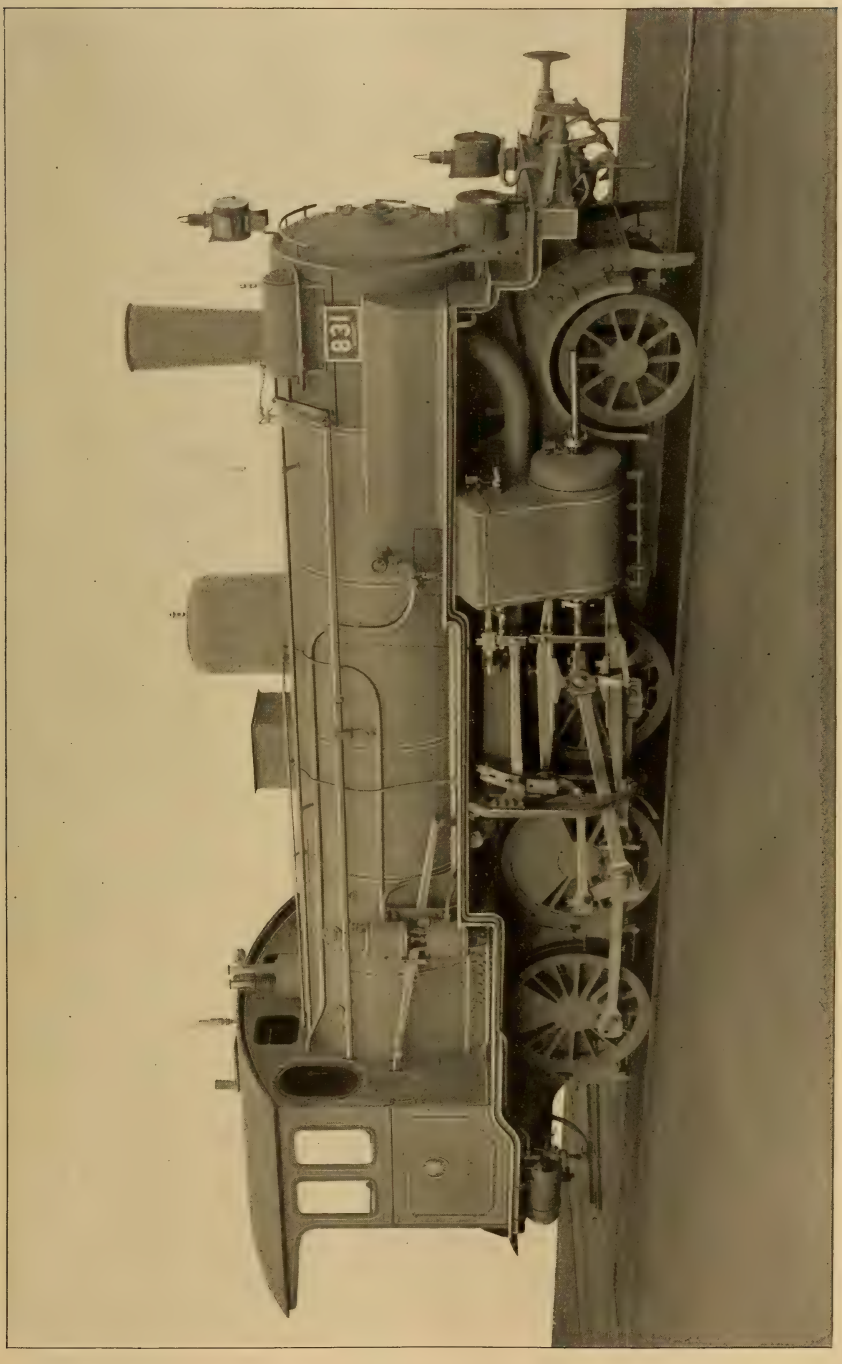


FIG. 2.—A MOGUL TYPE TWO-CYLINDER COMPOUND LOCOMOTIVE BUILT FOR PRUSSIAN GOODS TRAFFIC BY A. BORSIG, OF BERLIN

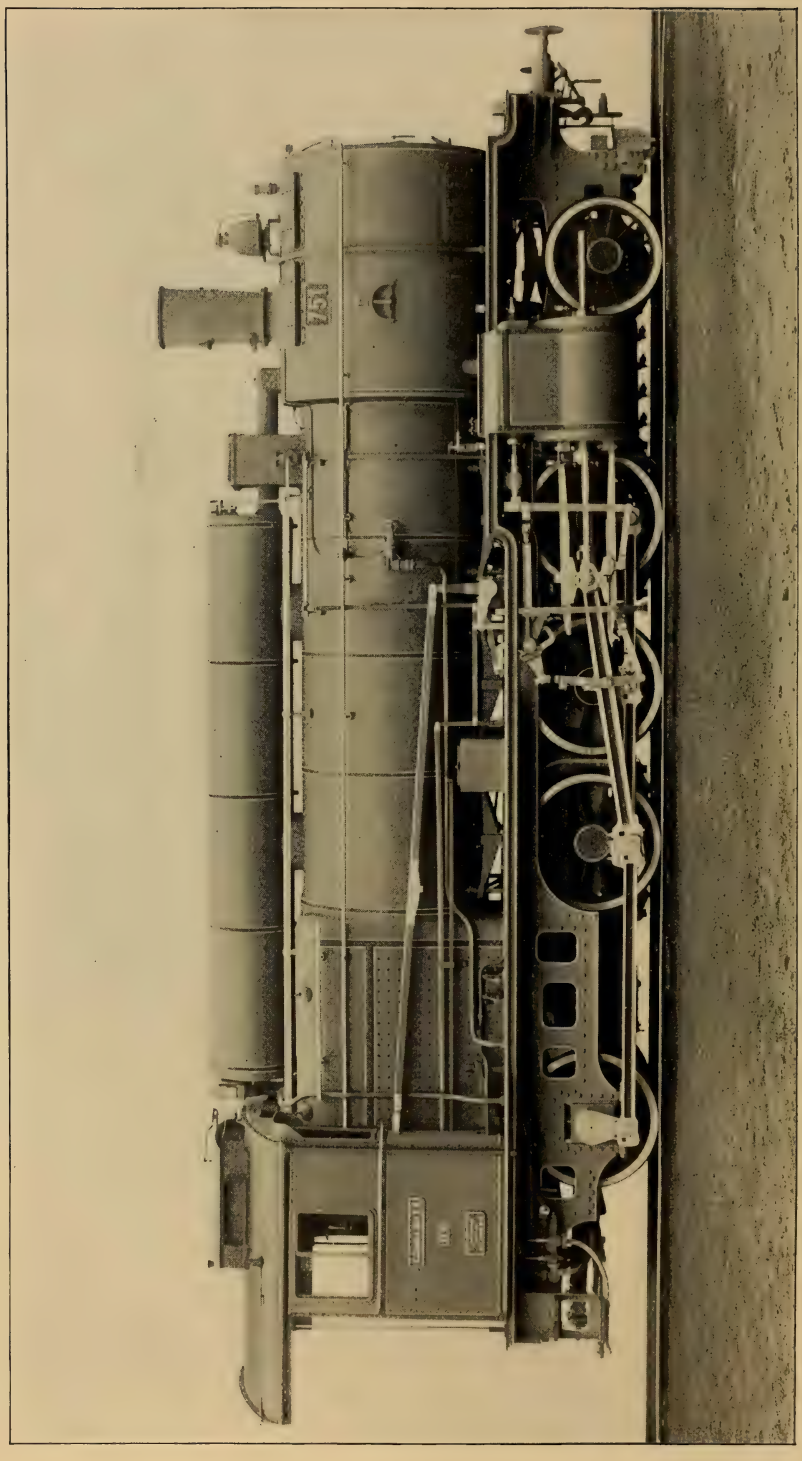


FIG. 3.—AN EIGHT-COUPLED, TWO-CYLINDER COMPOUND GOODS ENGINE BUILT BY THE SAECHSISCHE MASCHINENFABRIK, OF CHEMNITZ

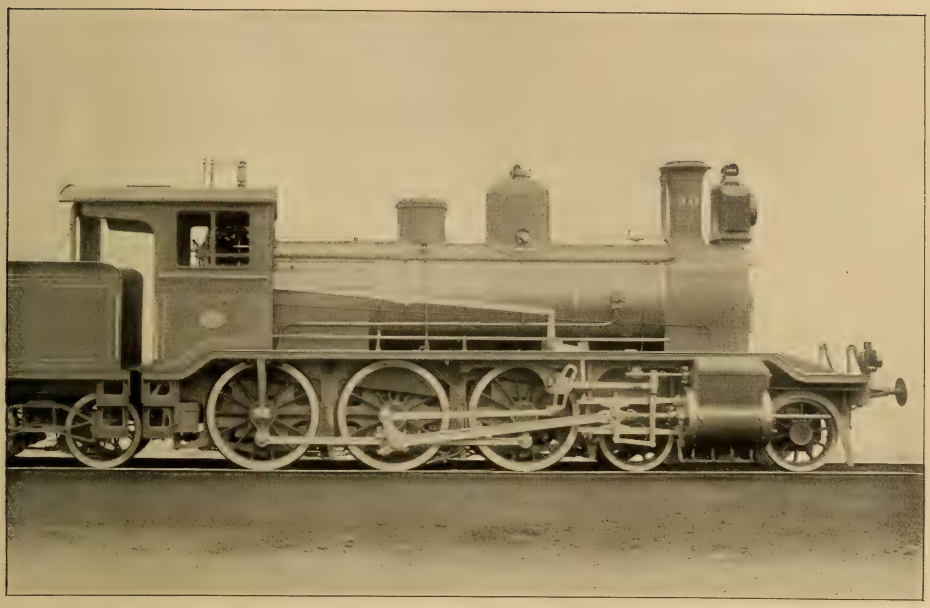


FIG. 4.—A NORWEGIAN STATE RAILWAY LOCOMOTIVE BUILT BY THE SAECHSISCHE MASCHINENFABRIK

service, and six-coupled, eight-wheel (Mogul type) engines for goods traffic. American practice gained more consideration after the inspection journey of the writer to the United States in 1891 and after the Chicago Exposition of 1893, and the result was distinctly advantageous to the German locomotive industry. Compound locomotives, too, had been developed to a satisfactory degree about that time. Following Mallet's initiative, the writer instituted trials with a simplified form of compound locomotive as far back as 1870. A number of prominent engineers, Gölsdorf, Lindner, and others, took part in this investigation, and the result was a general introduction in Germany of the compound system for nearly all main-line service. The new engines reduced the coal bills by from 10 to 25 per cent., and a proportionate increase in capacity was obtained from the same weight of engines.

The two-cylinder compound locomotive and the eight-wheel design for passenger service came in at about the same time, resulting in an eight-wheel compound engine with four wheels coupled, and this type has thus far done the greater part of the express service on the various German lines, and that, too, with a high degree of efficiency. Fig. 1 shows one of these engines, built for the Prussian Government railways by A. Borsig, of Tegel, near Berlin. The service weight of this engine is about 50 tons, and its normal capacity is 270 tons of train load at a speed of about 53 miles an hour on a level. The valve gear is all outside the wheels, and is of the Walschaert type, which is in general use in Germany as well as in most of the other Continental countries.

For starting compound locomotives several different mechanisms are in current use. Some of these are self-acting and give the low-pressure cylinder the necessary quantity of live steam only for the start; the others, handled by the driver, change the engine to simple action, with live steam and free exhaust from both cylinders.

Fig. 2 shows a six-coupled, eight-wheeler,—Mogul type,—also built by Borsig for Prussian goods traffic, with a service weight of about 50 tons, and about 7 tons on each of the driving wheels. In Fig. 3 we have an eight-coupled, ten-wheel compound engine

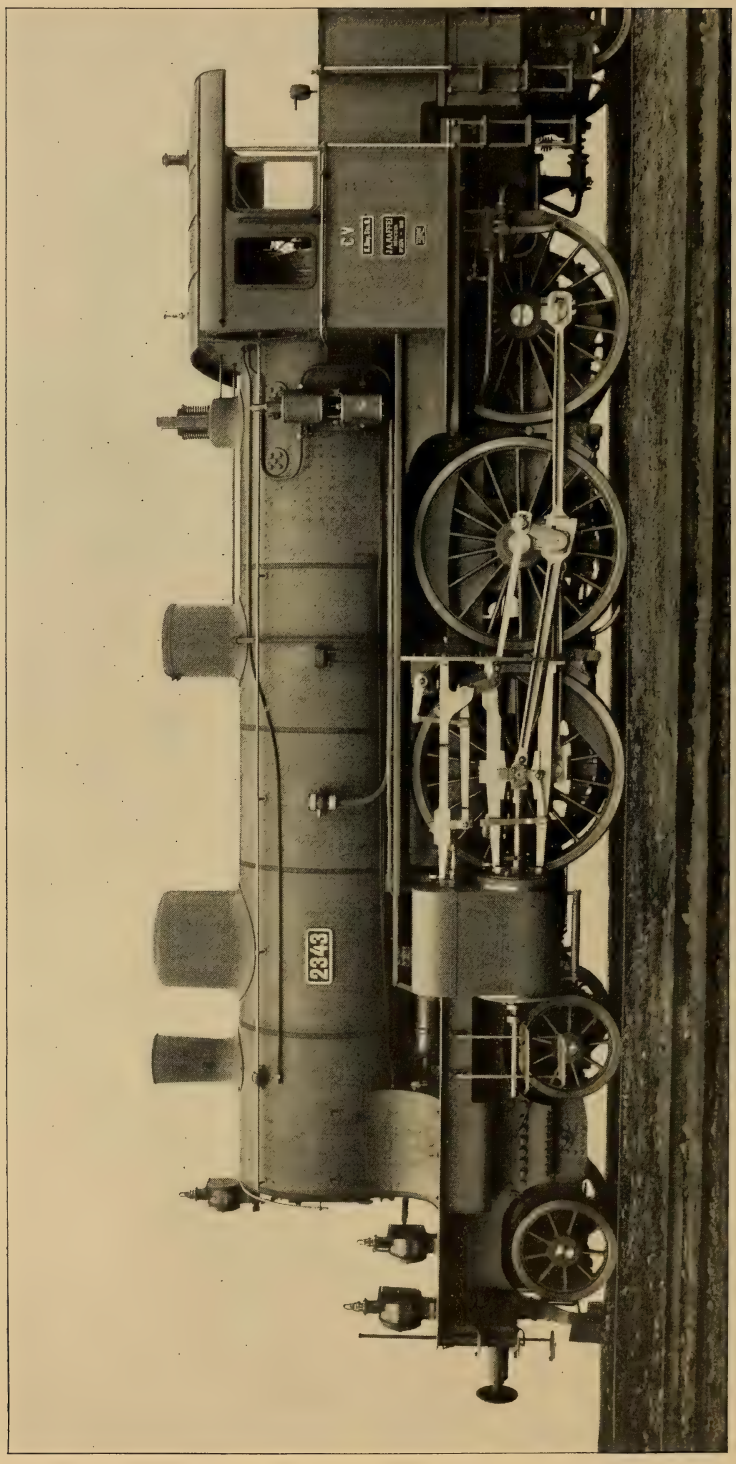


FIG. 6.—A FOUR-CYLINDER COMPOUND LOCOMOTIVE BUILT BY J. A. MAFFEI, OF MUENCHEN, FOR THE BAVARIAN STATE RAILWAYS. THE LOW-PRESSURE CYLINDERS ARE OUTSIDE, AND, IN STARTING, RECEIVE LIVE STEAM OF REDUCED PRESSURE THROUGH A SUITABLY GOVERNED VALVE

built in 1902 by the Sächsische Maschinenfabrik, of Chemnitz, for the Saxon State Railway. Another engine by the same builders, turned out for the Norwegian State Railway, and shown at the Paris Exposition, is illustrated in Fig. 4. This is a six-coupled, ten-wheeler with a service weight of 51 tons; each of the driving wheels carries about 6 tons.

Fig. 5 shows a locomotive, also in Norwegian service, built by the Swiss Locomotive Works, at Winterthur, who closely follow German practice. This

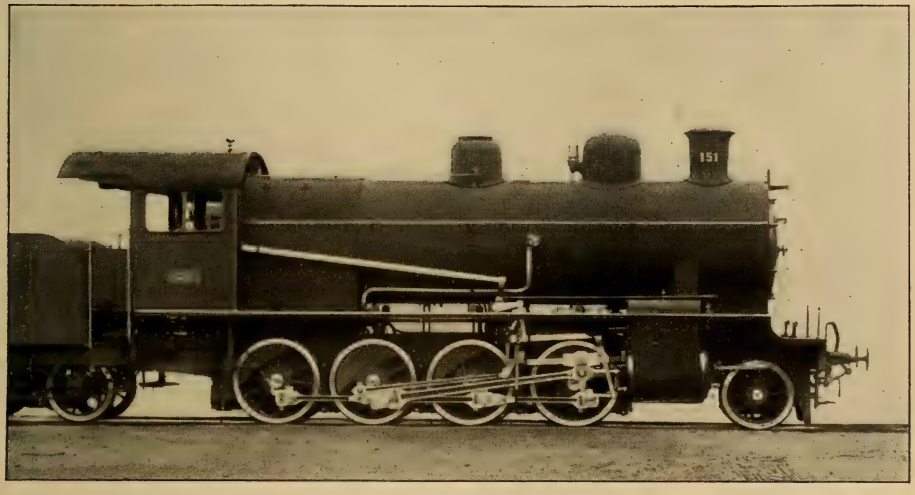


FIG. 5.—A LOCOMOTIVE FOR HAULING HEAVY ORE TRAINS ON NORWEGIAN RAILWAYS, BUILT BY THE SWISS LOCOMOTIVE WORKS, WINTERTHUR, SWITZERLAND

particular engine weighs 72 tons in service condition, and was designed for hauling heavy ore-trains.

With all the advances, however, that have been made towards heavier and more powerful engines in the period from 1890 to 1900, it was found that the traffic requirements grew in proportion, so that even before the year 1900 the conviction was apparent that still more powerful engines were needed. But, in characteristic German fashion, the efforts to build such engines were made in the direction of increased efficiency rather than still heavier dimensions, and as a logical result came the four-cylinder compound locomotive with large low-pressure cylinders, permitting a higher degree of expansion and the use of higher boiler pressures than had been previously employed, running up to about 240 pounds per square inch. The larger cylinders also afforded more tractive power for heavy-grade work. There was, too, a general increase of dimensions, with due regard, however, to the load restriction to 8 tons on drivers for passenger engines and 7 tons for the others.

The first locomotives of this type were six-coupled, ten-wheel engines for lines with heavy grades, all built on the De Glehn system, in which a pair of outside high-pressure cylinders is coupled to the middle or rear driving wheels, and a pair of inside low-pressure cylinders to the front drivers. The several driving wheels are so coupled that the inside and outside cranks of each side are in nearly opposite positions, with resulting balance of the reciprocating parts without counterweights in the wheels and consequent hammer-blow action on the rails.

The first of these engines was built in 1894 by the Elsässische Maschinenbau Compagnie, at Grafenstaden, of which works Mr. De Glehn is chief engineer, for the Schwarzwald line, well known for its difficult grades, as well as scenic

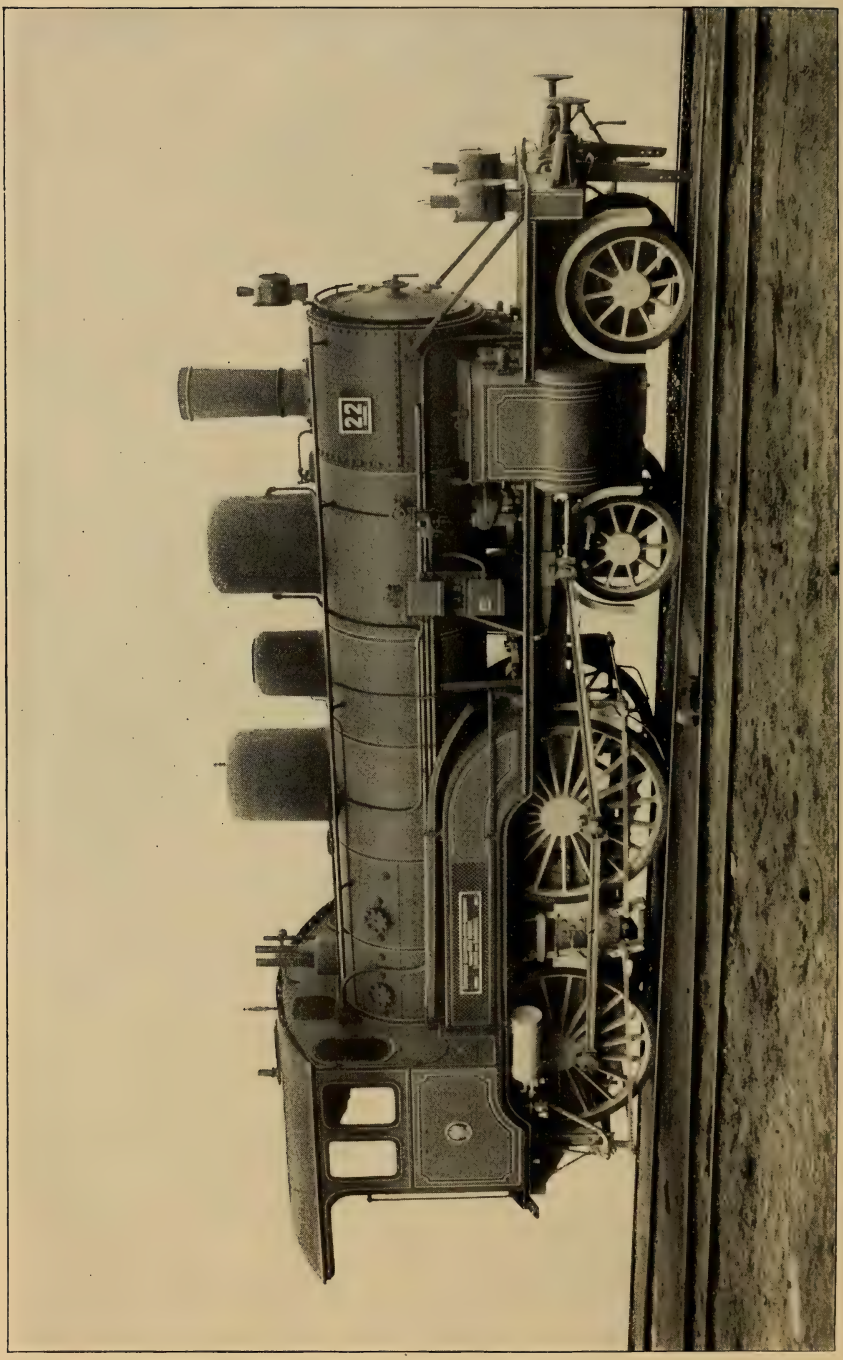


FIG. 8.—COMPOUND LOCOMOTIVE DESIGNED BY A. VON BORRIES AND BUILT BY THE HANNOVER MASCHINENBAU-AKTIEN-GESELLSCHAFT, HANNOVER. THE FOUR CYLINDERS IN THIS ENGINE ARE PLACED SIDE BY SIDE AT THE FRONT END, AND ALL FOUR PISTONS WORK ON THE SAME AXLE

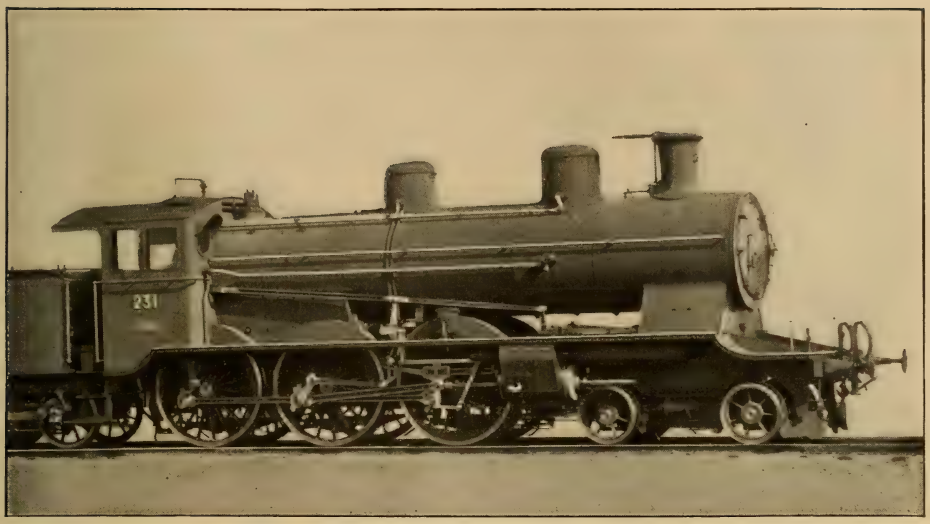


FIG. 7.—A FOUR-CYLINDER COMPOUND LOCOMOTIVE ON THE JURA-SIMPLON RAILWAY. BUILT BY THE SWISS LOCOMOTIVE WORKS. THE HIGH-PRESSURE CYLINDERS HERE ARE OUTSIDE AND THE LOW-PRESSURE CYLINDERS INSIDE

beauties. De Glehn, who had at that time also introduced his system on the Northern Railway of France, used independent governing gear for both sets of valves, enabling the engine-driver to run with the most suitable ratio of expansion in both pairs of cylinders. Change valves also permit the use of live steam in both pairs of cylinders, or in only one pair, as emergency may dictate.

Fig. 6 shows an engine of this class built for the Bavarian State Railways in 1896 by J. A. Maffei, of Munich. Here the low-pressure cylinders had to be put outside, and in starting they receive live steam of reduced pressure through a suitably governed valve.

Fig. 7 shows another locomotive of the same class, built in 1902 by the Winterthur Works for the Jura-Simplon Railway, in Switzerland, with the high-pressure cylinders outside and the low-pressure cylinders inside.

Since the year 1900 the constantly increasing speeds and train loads have led to the introduction of the four-coupled, ten-wheel class, which in the United States is known as the "Atlantic" class. These engines are all built on the four-cylinder compound principle. The first of the German ones of this type, built in 1900 by the Sächsische Maschinenfabrik, of Chemnitz, for the Saxon State Railway, is shown in Fig. 9. This engine was designed to haul the German Emperor's train at a speed of 62 miles an hour on the level, and engines of this type are still built on the De Glehn system, but with the valve gears of both pairs of cylinders governed by one handle and connected in such a way that the low-pressure cylinders have a 20 per cent. later cut-off than the high-pressure cylinders.

The complication of the De Glehn system and the inaccessibility of the inside gear prompted the writer in 1896 to design a simpler four-cylinder compound locomotive, with all four cylinders arranged side by side at the front end. All four pistons work on the same driving axle, and the cranks on each side are set in opposite directions with a view to securing balance of the reciprocating parts.

Fig. 8 shows the first engine of this class. It was built by the Hannover Maschinenbau-Actien Gesellschaft, and was shown at the Paris Exposition in 1900. Another engine of similar type

built by the same works is shown in Fig. 10. In running order the weight of this engine is about 64 tons, and its normal capacity is a train load of 300 tons hauled at a speed of 62 miles an hour on level track.

Another heavier locomotive of the same type, built in 1902 by J. A. Maffei for the Baden State Railway, is shown in Fig. 11. This engine has a service weight of 74 tons and a normal capacity of 300 tons of train weight at a speed of 68 miles an hour on a level, corresponding to about 1600 indicated horse-power. This exceeds the power of the well-known engines of the De Glehn type on the Northern Railway of France, and this particular engine may at present be considered to be the most powerful express locomotive in the world.

Some time after the introduction of the four-cylinder compound locomotive in 1897 Mr. W. Schmidt, of Wilhelmshöhe, best known from his work in connection with superheated steam, proposed using superheaters on locomotives, and his plan met with favour by Mr. Garbe, one of the high officials of

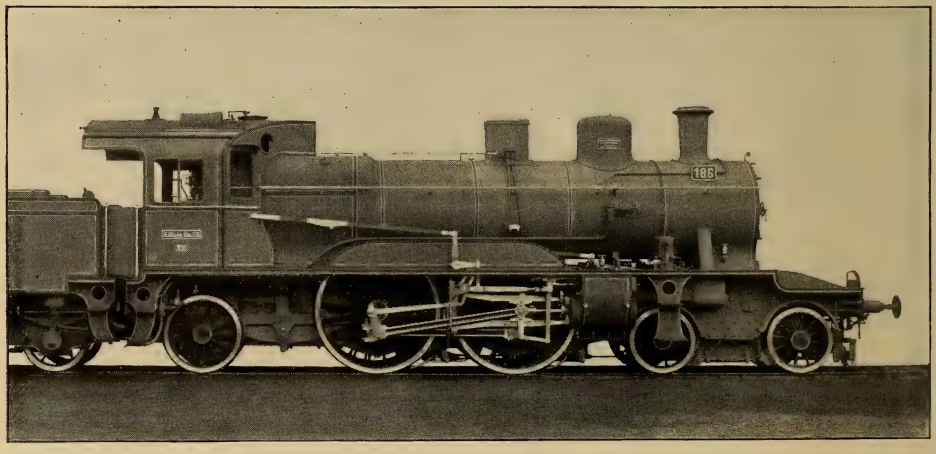


FIG. 9.—AN ATLANTIC TYPE FOUR-CYLINDER COMPOUND LOCOMOTIVE BUILT BY THE SAECHSISCHE MASCHINENFABRIK, AT CHEMNITZ. THIS REPRESENTS ONE OF THE EARLIEST GERMAN ENGINES OF THAT TYPE

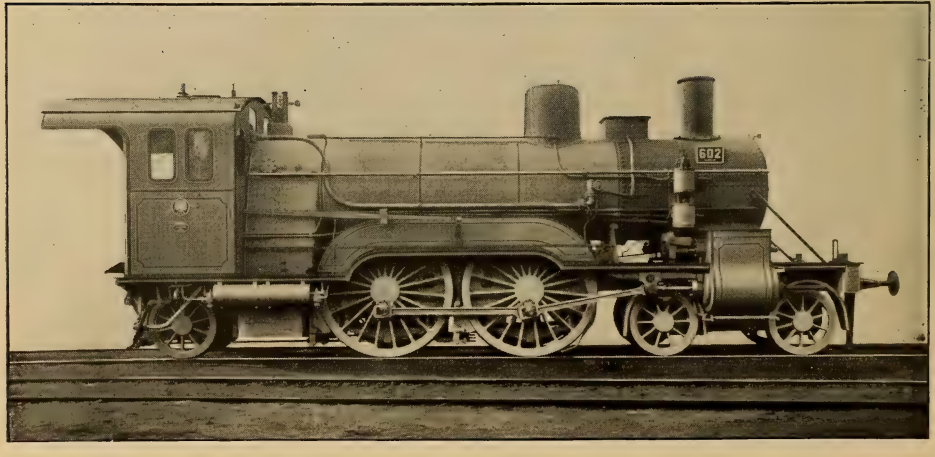


FIG. 10.—A COMPOUND LOCOMOTIVE SIMILAR IN DESIGN TO THE ONE SHOWN IN FIG. 8

the Prussian State Railway. Mr. Schmidt proposed to superheat the steam up to about 480 degrees Fahr. For this purpose he conducted a portion of the furnace gases through a wide flue at the bottom of the boiler to the smoke-box, and there these gases entered the superheater at a very high temperature. The superheater itself consisted of a collection of small flues through which the steam was made to pass on its way from the boiler to the cylinders, while the flue gases passed around the outside. The superheater heating surface was about one quarter of the inside heating surface of the boiler.

The first superheated steam locomotive was built by the Vulcan Works, at Stettin, and was delivered in 1898 to the Hannover division of the Prussian State Railway. Several additional engines of the same type followed within the next two years, one of them having been built at the Borsig Works and shown at the Paris Exposition of 1900. The weight of this engine was about 56 tons, with a capacity of 300 tons of train load at a speed of 56 miles an hour on the level.

The high temperature of the furnace gases in the superheater and of the superheated steam itself led to a number of difficulties, which, however, were gradually

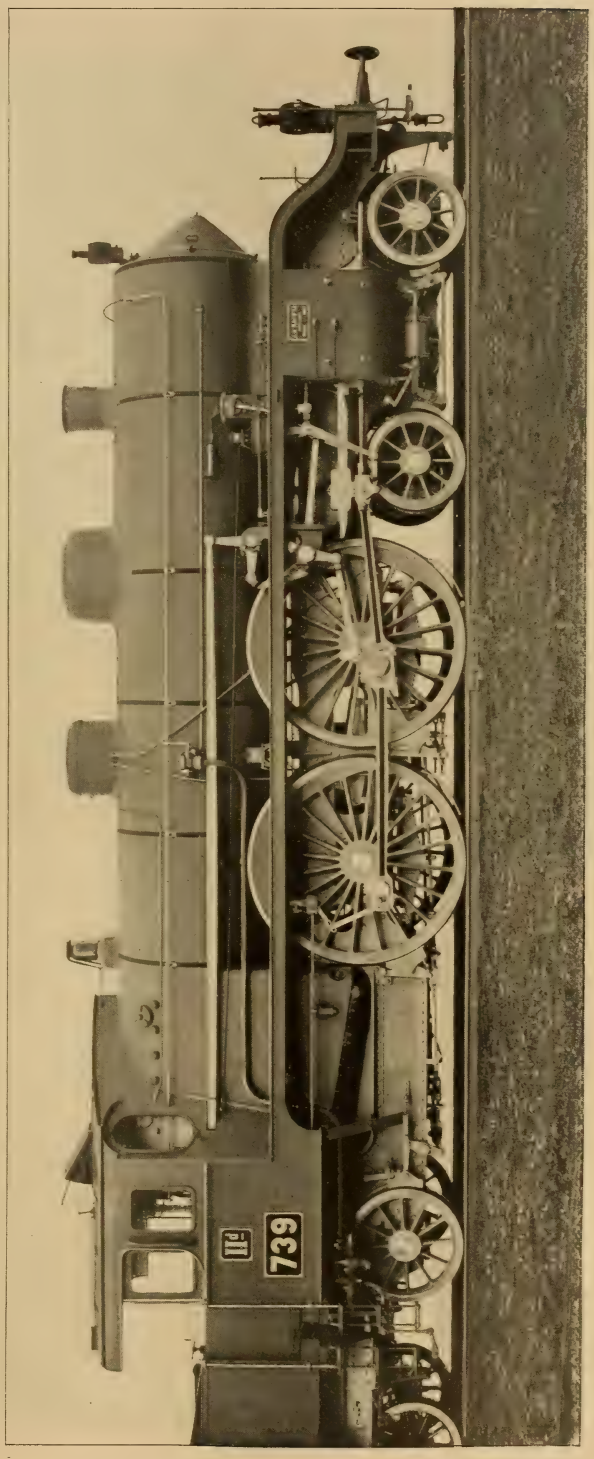


FIG. 11.—A FOUR-CYLINDER COMPOUND HEAVY PASSENGER LOCOMOTIVE BUILT FOR THE BADEN STATE RAILWAY BY J. A. MAFFEI, OF MUENCHEN

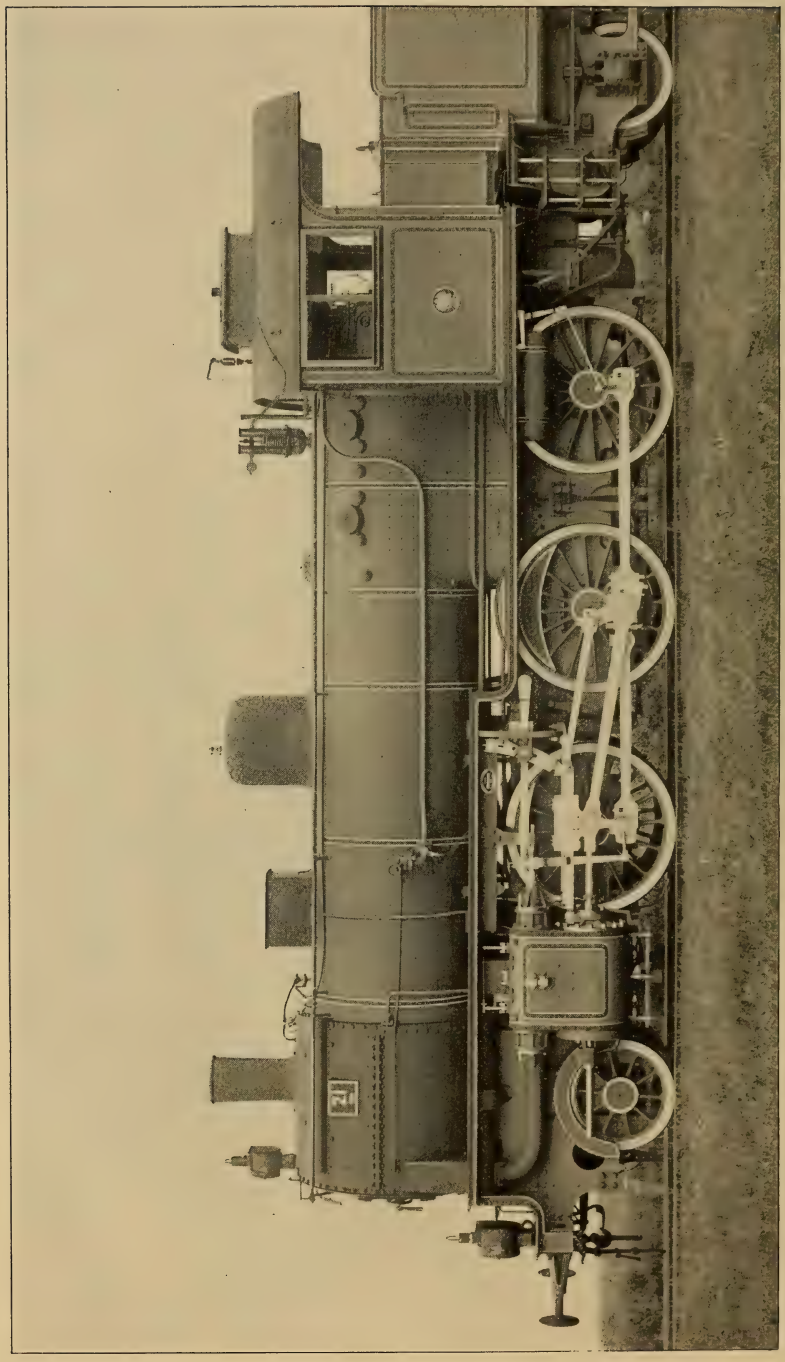


FIG. 12. A LOCOMOTIVE FOR HEAVY PASSENGER AND GOODS TRAFFIC BUILT BY THE HOHENZOLLERN LOCOMOTIVE WORKS, DUESSELDORF. SUPERHEATED STEAM IS USED IN THIS ENGINE, THE SCHMIDT SYSTEM BEING EMPLOYED

and successfully overcome by the painstaking efforts of Mr. Schmidt and Mr. Garbe, and a number of such engines, all of them non-compound, and intended both for passenger and goods traffic, were built in 1901 and 1902. Numerous trials were made with these locomotives, especially on the Hannover and the Saarbrücken divisions of the Prussian State Railway, and the results showed that the express engines were about equal in economy and capacity to the ordinary four-cylinder compounds, and that the goods engines yielded a small economy in coal for the same work, as compared with two-cylinder compounds of several tons less weight. In point of fact, a rather more favourable result might have been expected, and it may be presumed, therefore, that some of the details have not yet been brought to an entirely satisfactory working point.

Fig. 12 shows a superheated steam

FIG. 13.—A NARROW-GAUGE ENGINE BUILT BY THE KRAUSS LOCOMOTIVE WORKS, MUENCHEN

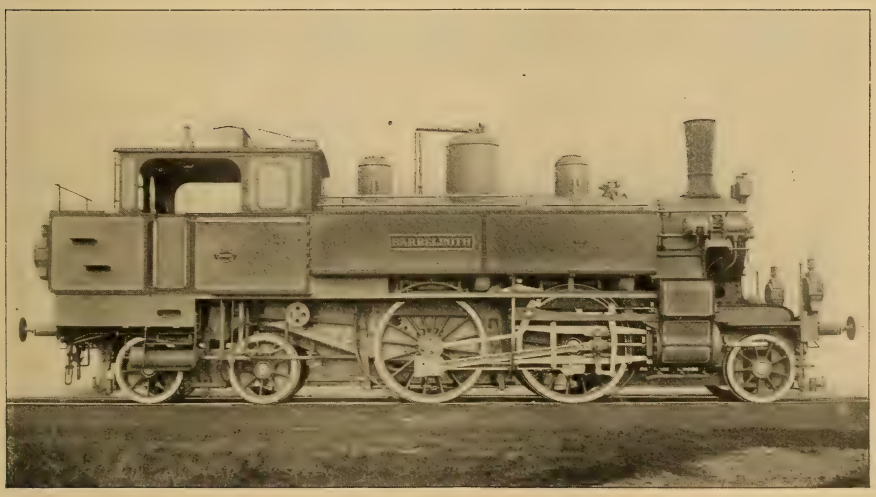


FIG. 14.—A TANK ENGINE BUILT BY THE KRAUSS LOCOMOTIVE WORKS

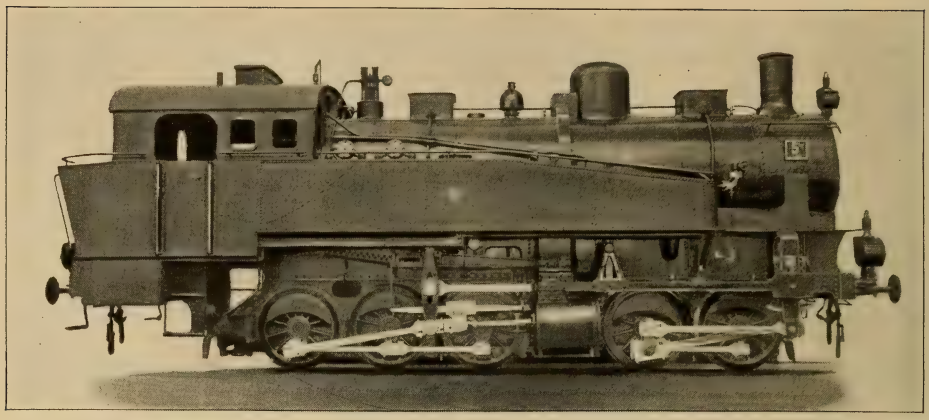


FIG. 15.—TANK ENGINE BUILT BY THE HAGANS LOCOMOTIVE WORKS, OF ERFURT

locomotive of the six-coupled, eight-wheel type, built in 1902 by the Hohenzollern Locomotive Works, at Düsseldorf, and exhibited there at the exposition of 1902. This engine is intended for both heavy passenger and goods traffic. The leading wheels and the first pair of coupled wheels are grouped in a Krauss bogie truck, which, on curves, enables the leading wheels to take a radial position and the front pair of coupled wheels to have some lateral motion, thus contributing to easy running.

One noteworthy specialty in recent German locomotive design has been the tendency to make the wheel base as flexible as possible, a practice which is well illustrated in Fig. 14, which represents a four-coupled, ten-wheel passenger tank engine built by the Krauss Locomotive Works, of Munich, for the Bavarian State Railway. In this engine only the driving axle is rigid. The leading wheels and the front pair of coupled wheels, as in the preceding example, form a Krauss truck, the rear end of the engine being supported on an ordinary bogie truck. This flexibility is conducive to very smooth running on curves, and also insures greater steadiness on straight sections of track.

The Krauss truck consists of a frame, triangular in plan, the base being formed by the front carrying axle, and the point is articulated to the transverse frames connected to the boxes of the coupled axle. The whole system turns around a pin secured to the main frame in such a way that the convergence of the front axle insures a rectilinear displacement of the second axle in an opposite direc-

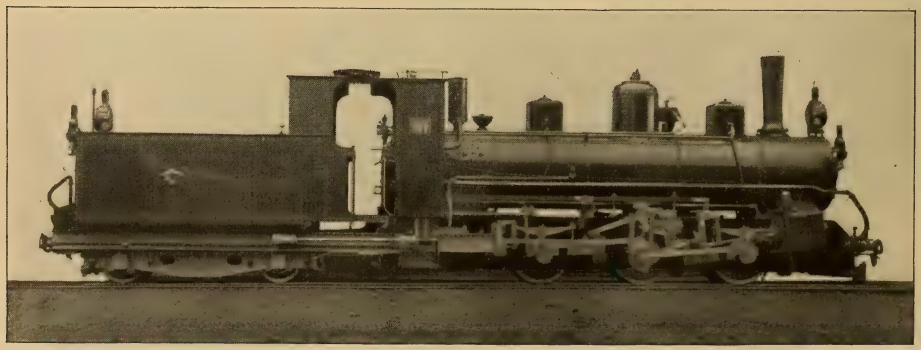


FIG. 16.—A FLEXIBLE WHEEL BASE LOCOMOTIVE, KLOSE TYPE, BUILT BY THE KRAUSS LOCOMOTIVE WORKS

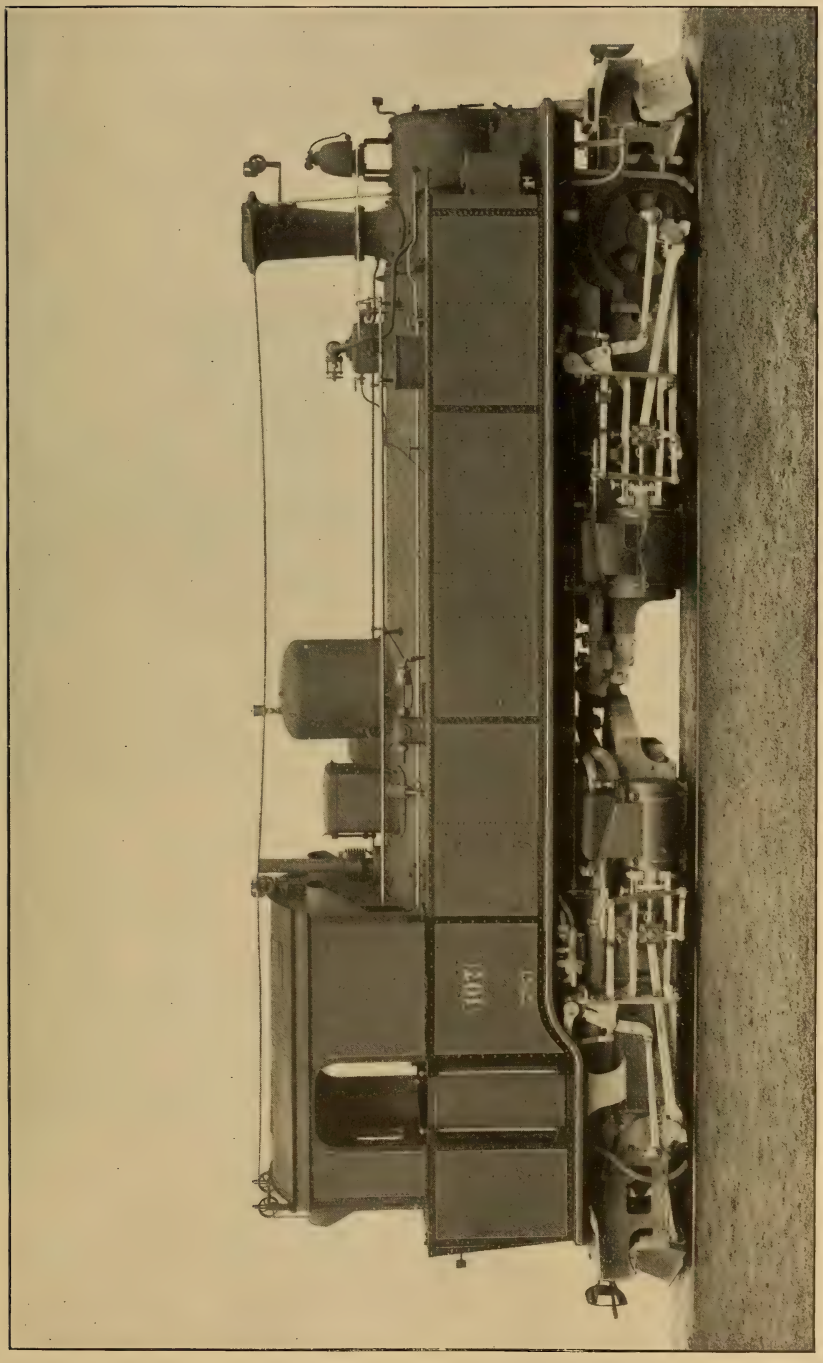


FIG. 17.—A MEYER COMPOUND LOCOMOTIVE, NARROW GAUGE, BUILT BY THE SAECHSISCHE MASCHINENFABRIK, AT CHEMNITZ. THE FRONT BOGIE CARRIES THE LOW-PRESSURE AND THE REAR BOGIE THE HIGH-PRESSURE CYLINDERS

tion. The arrangement combines the advantages of a bogie with that of useful adhesion on one pair of wheels. It may be mentioned here that the Krauss truck has been applied in Germany to more than 600 locomotives of all types and dimensions.

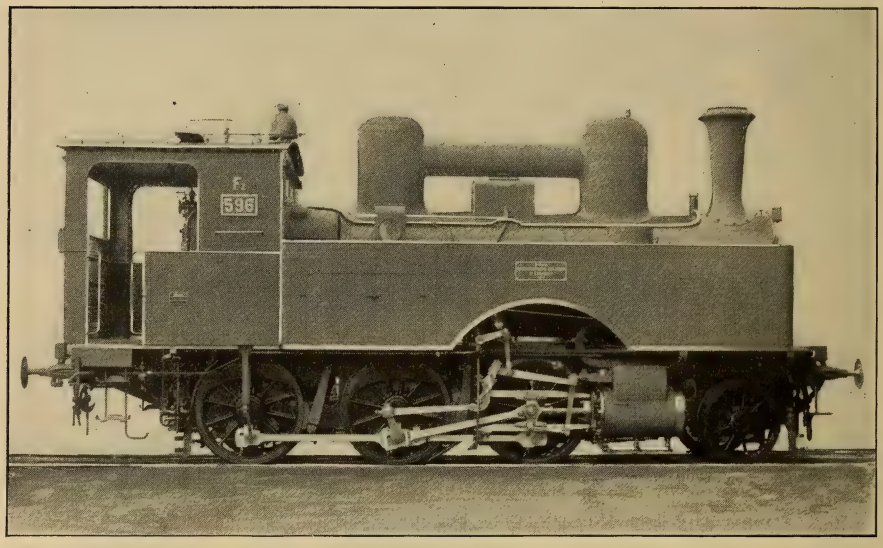


FIG. 18.—AN ABT SYSTEM RACK RAILWAY LOCOMOTIVE, BUILT BY THE ESSLINGEN MACHINE WORKS, ESSLINGEN

Not only the Krauss truck, but others also, of 'somewhat similar' construction, are extensively used in Germany for locomotives of all sizes. Fig. 13, for example, shows a light, narrow-gauge locomotive of only about 26 tons service weight, built by the Krauss Works, in which the main frames are widened back of the driving wheels around the firebox. This type of engine is in extensive use on some of the light, narrow-gauge railways.

Giving the driving wheels a certain amount of lateral freedom,—from about a quarter of an inch to half an inch,—is a widening practice with German builders, and has led to very satisfactory results. Experience would seem to show that it leads to easier running on curves than the flat, flangeless tires used for that purpose on British and American engines.

On lines where there are many sharp curves flexible motor-bogies and radial driving axles are used. The history of these devices, upon which much time and ingenuity has been expended, goes back more than fifty years, when a competition for a locomotive with so-called flexible drivers was arranged for one of the Austrian railways noted for its very heavy grades and sharp curves. Nearly all the early devices of this kind were flat failures, but in recent years improved designs have been introduced, and with some of these very good results have been obtained. Fig. 17, for example, shows what is known as a Meyer type of locomotive. It is a narrow-gauge engine built for the Saxon State Railway by the Sächsische Maschinenfabrik, at Chemnitz. There are two pairs of cylinders, working compound, the rear bogie carrying the high-pressure and the front bogie the low-pressure cylinders. The steam pipes have flexible connections.

The Mallet system is also used in Germany for service on lines with sharp curves. In the Mallet locomotive the rear part of the driving gear with the high-pressure cylinders is placed on the main frame of the engine, and only the front part which carries the low-pressure

cylinders, is placed on a bogie truck. With this engine, however, there is not quite that full degree of freedom on curves that the Meyer engine secures. A large Mallet locomotive, as built by J. A. Maffei, is shown in Fig. 21. This engine was one of those exhibited at Paris in 1900.

In all locomotives with so-called motor-bogie trucks the various connections on the frames and cylinders require careful attention, because of the exceptional strains and vibrations set up in the trucks themselves.

Another system in which the bogie is driven from the main driving gear by lever connection is that of the Hagans Locomotive Works, of Erfurt. Fig. 15 shows a large tank locomotive built after this plan. The four front driving wheels are arranged as a bogie truck connected to the main frame by a rear pivot bolt.

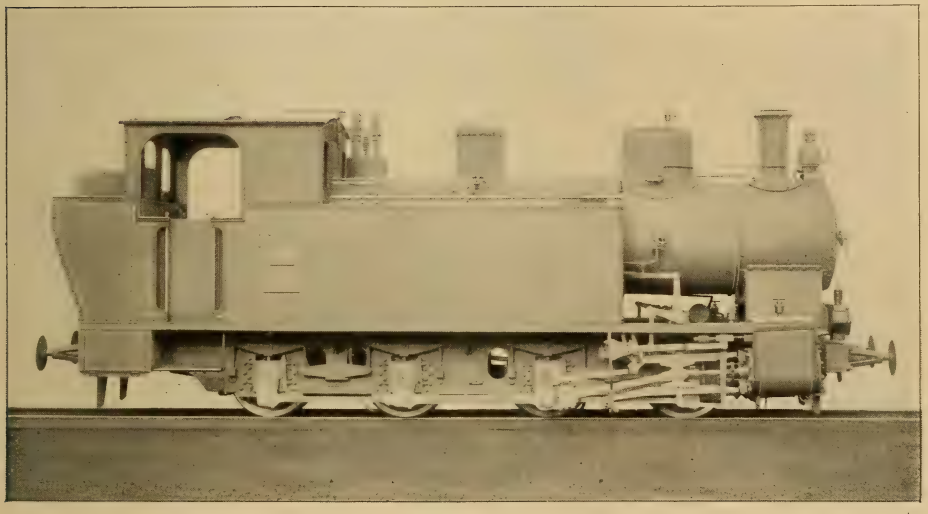


FIG. 19.—A NARROW-GAUGE TANK ENGINE BUILT BY THE SAECHSISCHE MASCHINENFABRIK

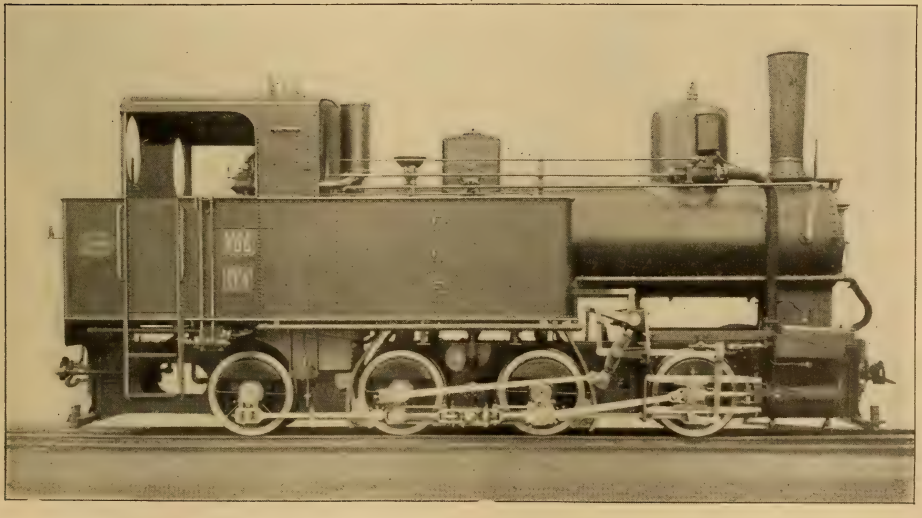


FIG. 20.—A TANK ENGINE, HELMHOLZ SYSTEM, BUILT BY THE KRAUSS WORKS

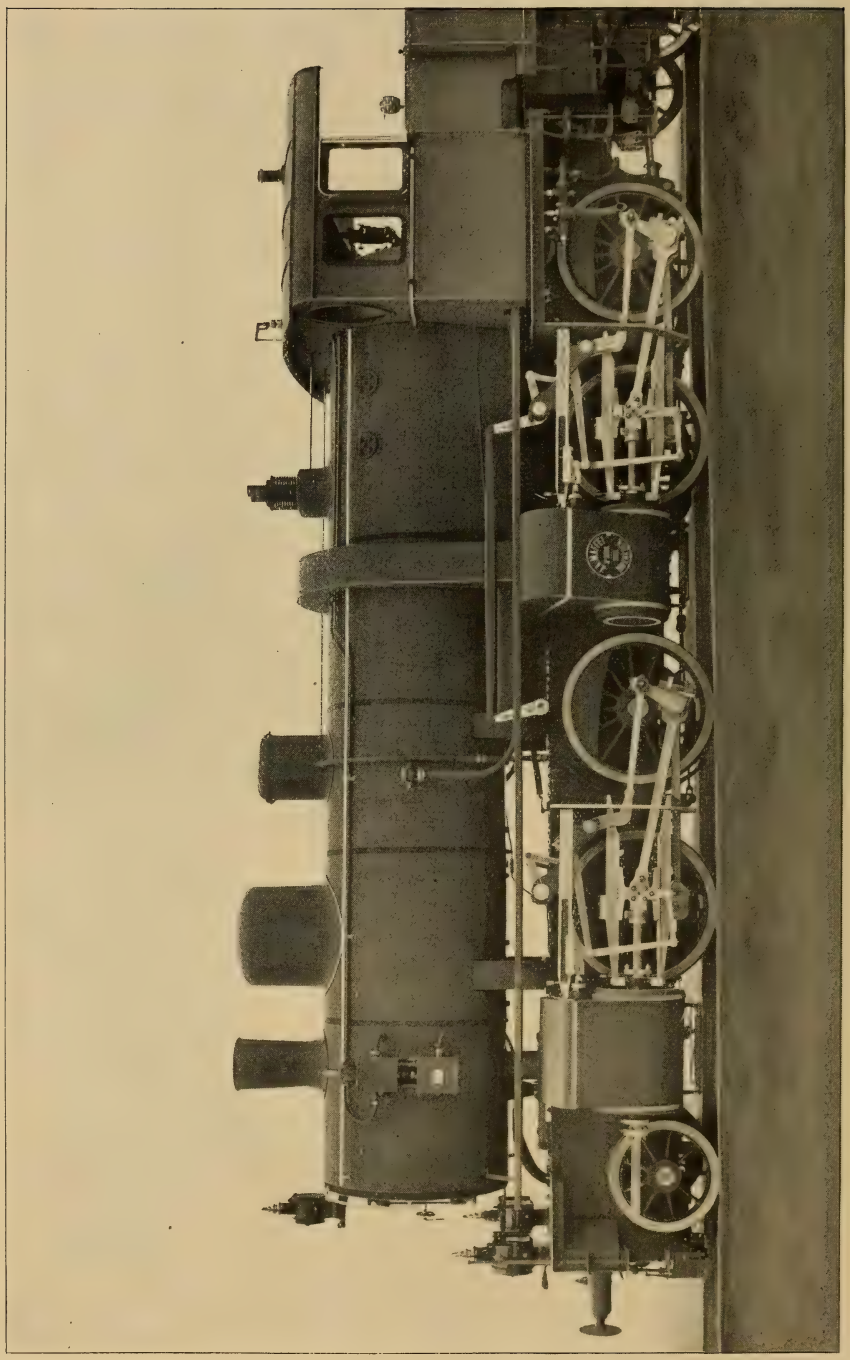


FIG. 21.—A MALLETT COMPOUND LOCOMOTIVE BUILT BY J. A. MAFFEI, OF MUENCHEN

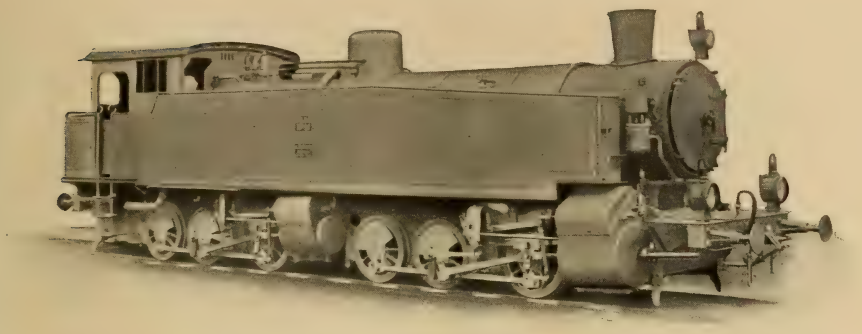


FIG. 22 —A FOUR-CYLINDER COMPOUND 108-TON TANK LOCOMOTIVE BUILT BY A. BORSIG, TEGEL, NEAR BERLIN. THE MOST POWERFUL LOCOMOTIVE OF ITS KIND IN THE WORLD. THE HIGH-PRESSURE CYLINDERS WHICH DRIVE THE THREE REAR PAIRS OF WHEELS ARE FIXED ON THE MAIN FRAME WHICH CARRIES THE BOILER, SO THAT THERE ARE NO FLEXIBLE STEAM PIPES UNDER BOILER PRESSURE. THE LOW-PRESSURE CYLINDERS DRIVE THE THREE FRONT PAIRS OF WHEELS, WHICH ARE CARRIED BY A SEPARATE FRAME, HINGED TO THE MAIN FRAME IN THE PLANE OF THE HIGH PRESSURE CYLINDERS, THUS ALLOWING THE ENGINE TO TAKE SHARP CURVES EASILY; IN FACT, IT MAY BE COMPARED IN THIS RESPECT TO TWO SIX-COUPLED ENGINES UNDER ONE BOILER. THE EXHAUST FROM THE HIGH TO THE LOW-PRESSURE CYLINDERS IS CARRIED THROUGH PIPES WITH STUFFING BOXES TO PERMIT OF THE NECESSARY RADIAL MOTION

The main crosshead is connected to a combination of levers which drive the main cranks. The connections can be traced out by a close examination of the illustration, which, in a general way, perhaps gives the best idea of the system. In a locomotive of this type flexible steam pipe connections are avoided, and also complication in the matter of cylinders.

Another class of locomotive with flexibly driven wheels is that in which the rear axles have radial motion. An engine of this type is shown in Fig. 16, representing what is known as a Klose engine, built by the Krauss Works, of Munich,—in this particular instance for one of the military railways of Bosnia. The bearings of the rear axle are controlled by rods, movable longitudinally and connected by levers in such a way that they take corresponding positions, controlled either by the lateral movement of the middle axle or by the angular position of the tender, as in Fig. 16. On the Württemberg State Railway a large number of locomotives of this kind are in service. Another type of engine designed to accomplish the same purpose is shown in Fig. 19. This is a tank engine built by the Chemnitz Works for the narrow-gauge Silesian railways.

Still another engine which should be classed with the ones just referred to is that shown in Fig. 20. This illustrates what is known as the Helmholz system.

The engine is a tank design, also built by the Krauss Works for one of the Bosnian railways. Here the two end axles and the ones next to them are arranged in Krauss-Helmholz bogies, and both bogies are connected at the centre so that the radial position of the end axles is governed by the lateral movement of the middle axles. There is a somewhat complicated arrangement of coupling rods and equalising levers, which, in part at least, is shown in the illustrations.

The illustrations in all these cases must be left largely to tell their own stories, as it would be impossible in an article of this kind to properly take up their details. Experience alone will show which of these several systems is the most suitable and economical. For the present all of them have given a fair degree of satisfaction. Instead of bogie motors and radial drivers, a double-engine arrangement is sometimes used. Fig. 22 shows a twin engine of this kind.

Locomotives for rack railways are built principally by the Esslingen Works, at Esslingen, in Germany, and

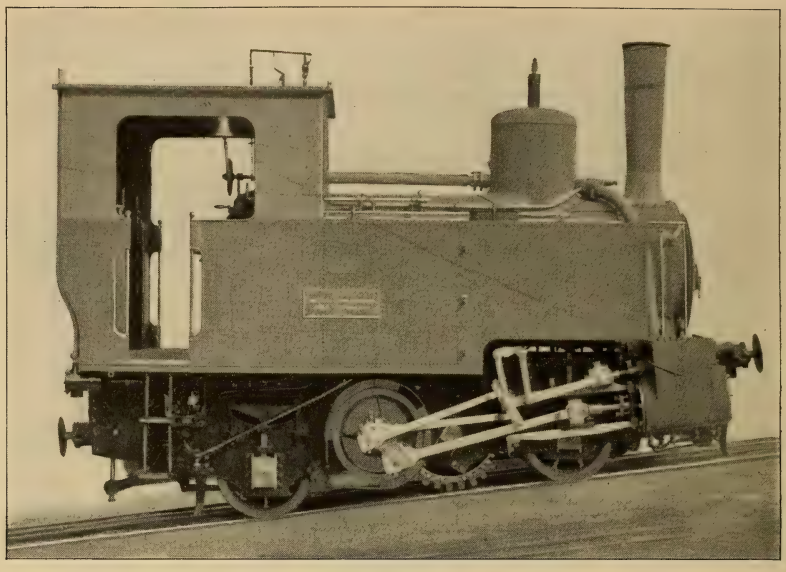


FIG. 23.—A RIGGENBACH RACK LOCOMOTIVE FOR MOUNTAIN SERVICE. BUILT BY THE ESSLINGEN MACHINE WORKS, ESSLINGEN

by the Winterthur Locomotive Works, in Switzerland, the Abt system being the one generally employed. In these locomotives the rack and the ordinary adhesion driving gears are operated by different sets of cylinders. Fig. 18 shows one of these locomotives. Fig. 23 shows a rack locomotive of the Riggenbach type for mountain service. In this engine there is only a rack driving gear, as the grades on which the locomotive is to be used are so steep that an adhesion gear would be entirely useless.

The various illustrations accompanying this article are excellently indicative of what German locomotive builders are doing. In point of size of locomotives, it must be borne in mind that German tendency is towards efficiency rather than great size, and that the load on driving wheels is still limited to a low figure. Moreover, there is no demand for such heavy trains as are now common in Great Britain and the United States, and this circumstance naturally is reflected in the character of the engines turned out at the different works.

THE MICROSCOPE IN ENGINEERING

ITS WIDENING USE IN STUDYING THE STRUCTURE OF METALS

By J. L. Hall

ENGINEERS base their selection of material on their knowledge of its peculiarities. From many years of experience in both laboratory and mill a vast amount of data, relating to both physical and chemical qualities, has been acquired. By careful scientific testing the values given to the constants which enter into engineering formulæ have been determined, and practice has demonstrated their truths; yet to-day how far from absolute confidence is the feeling of firm security regarding calculations! The use of the empirical factor of safety, historic sometimes and arbitrary always, the figure 6, is positive proof of a feeling of insecurity in materials, and we endeavour to shield our ignorance of the strength of the materials entering into a design by holding up before us as an apology our lack of knowledge in originating the design itself.

Quality in the grade of metal used in structures and mechanical appliances has in the past been considered synonymous with chemical composition; yet to-day we are quite sure this is not absolutely true. Of late another factor has gradually crept in which has a far-reaching and most important bearing on the question of quality. I refer to heat treatment. The old saying, "True as steel," no longer typifies reliability. To aid in ascertaining the reasons for unexplained failures engineers have turned to the microscope, in the hope that at last many enigmas would be solved.

It may be well to state here that the microscope is not expected to answer every question which has arisen regarding materials. Neither can we hope always to apply the knowledge we have obtained by its use to a practical end. Its reliability in determining the physical properties of steel, for instance, has often been questioned. Most sweeping were the claims for results of chemical investigations when they were first applied in manufacturing, and much was expected from them which, it has since been proved, was beyond their inherent power to accomplish. All sciences have their limitations. So it is with metallography,—the name generally given to the science which applies the microscope to ascertain the structure of metals and alloys.

Metallography, however, is not a purely descriptive science, or its application to the various lines of industrial work would be extremely limited. It goes much farther and deals with the relation between structure and those properties upon which the value of metals depends.

It is difficult to fix the date of the production of the first microscope as distinguishable from a mere magnifying lens; but it was probably about the year 1600, and evidence points to Galileo as the man who developed it. Its history, while interesting in the abstract, can only be referred to here. To the first instrument improved objective eye-pieces and accessory apparatus were added, new designs permitting of finer adjustments were adopted, until to-day the microscope is an instrument of the greatest precision and usefulness. The needs of metallography have, in late years, made new demands, requiring special modifications in the auxiliary apparatus; but, in general, the microscope of the metallographist is also the microscope of the botanist and the biologist.

To a student, Dr. Henry Clifton

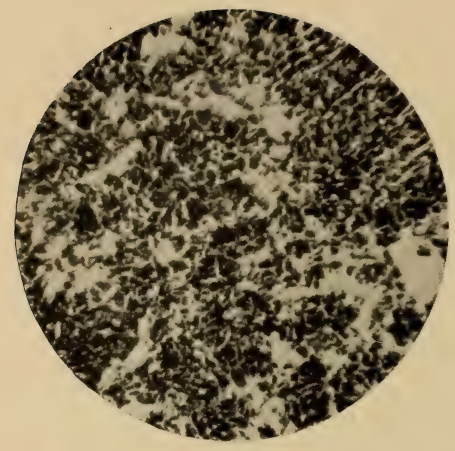


FIG. 1.—PHOTO-MICROGRAPH OF STEEL AFTER HEATING TO 750° C. AND COOLING IN THE AIR. MAGNIFIED 100 DIAMETERS

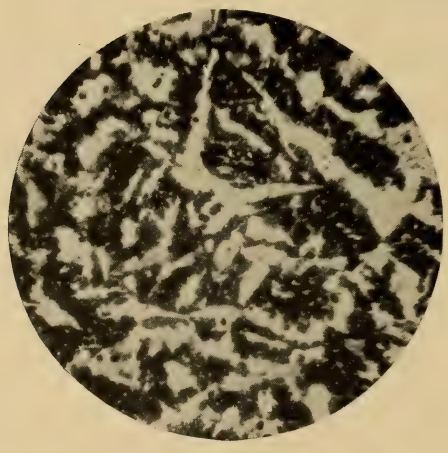


FIG. 2.—STEEL AFTER HEATING TO 750° C. AND COOLING IN THE FURNACE

Sorby, of Sheffield, England, is due the honour of the pioneer work in metallography. All other workers in the field, both scientists and engineers, who have since helped so materially to develop this branch of science to its present condition of exactitude have followed Dr. Sorby's footsteps. Not directly interested in metallography, but a student of geology and mineralogy, he applied the microscope to the study of rocks, and it was for him a natural and sequential step to apply it to the investigation of metal structures.

Yet, when he presented a paper in 1864 before the British Association, treating of this method of examination, he attracted little attention, and the paper was merely filed for future consideration, which it did not receive until twenty years later, when the Iron and Steel Institute invited Dr. Sorby to become a member of a committee selected to investigate the practicability of applying the microscope in the examination of the internal structure of steel. The result of this action was a second paper by Dr. Sorby, which should be considered the first milestone on the road between the adoption of the microscope for purely scientific research and its application to practical uses by the engineer.

Probably everything has its strong points as well as its weak ones. Should the advantages of a particular device outweigh its disadvantages, we adopt it; *vice versa*, and we discard it. So in considering the use of the microscope in engineering, we must balance the arguments for and against it. Why should the engineer, and by this term is meant not only the individual in his capacity as a scientific analyst, but the industrial engineer as well, consider any new method of testing his materials? Has he not already a well-developed system of investigation covering tensile, torsion, compression, and drop tests?

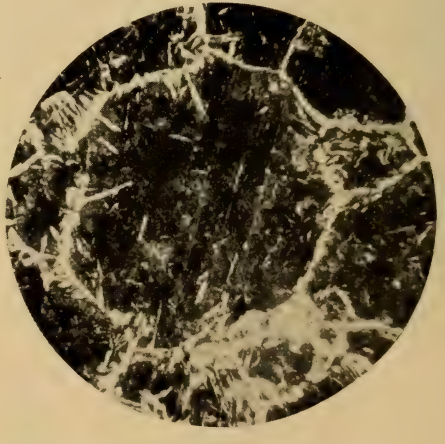


FIG. 3.—STEEL AFTER HEATING TO 1000° C. AND COOLING IN THE AIR

Does not chemical analysis tell all about the composition of metals? Does he not know that so many hundredths of one per cent. of phosphorus make steel brittle? So much sulphur, red short? In any case, if it be suspected that something is wrong, cannot a piece of the metal be cut directly from the thing itself, turned into a half-inch test piece and put through certain destructive processes to prove, perhaps, the truth of the suspicion?

Can he not break a 1-inch bar into pieces and note the fracture, a coarse appearance implying weakness, while a fine grain signifies strength? Can he not treat his metal with some suitable reagent and find the cause of the trouble? What if the material is defective! He can discover the fault by one of these two methods, and a knowledge of the structure of metals is of little importance. Such are some of the arguments against the use of the microscope in testing. Do these arguments stand upon a sound foundation of fact?

Granting that the testing machine will reveal defective material, we know from its use merely that certain pieces are defective. But what will be the next step in the investigation of the cause? Why should we not expect the next casting or forging to be just as defective? We have not diagnosed the case, far less suggested the remedy. But we can certainly ascertain a remedy, we are told, by chemical investigation, and, in truth, chemical composition and physical properties are closely affiliated; but a glance at the annexed illustrations will make it sufficiently clear that there is a factor entering into the strength of the metal not chargeable to the component elements. Fig. 1 shows the structure of a piece of steel magnified 100 times. This piece contains 0.33 per cent. of carbon, 0.60 per cent. of manganese, 0.065 per cent. of sulphur, 0.56 per cent. of phosphorus, and has been heated to 750 degrees C. and cooled in the air. Fig. 2 shows a piece of the same steel, heated to the same temperature, but cooled in the furnace. Figs. 3 and 4 show the same steel after heating to 1000 degrees C., and, respectively, air and furnace cooling.

The Fig. 1 specimen had a tensile strength of 89,000 pounds per square inch, with an elongation of 26 per cent. in 2 inches; No. 2 showed 78,680 pounds tensile strength, with 29 per cent. elongation; No. 3, 102,850 pounds and 23.5 per cent. elongation; and No. 4 showed 81,650 pounds, with 26 per cent. elongation. The maximum variation in tensile strength, therefore, is 30.5

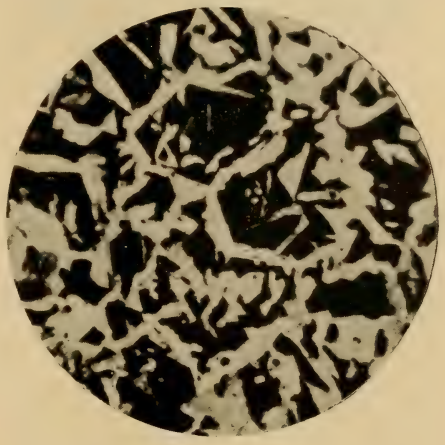
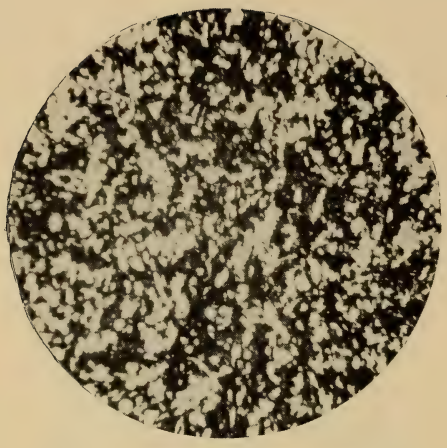


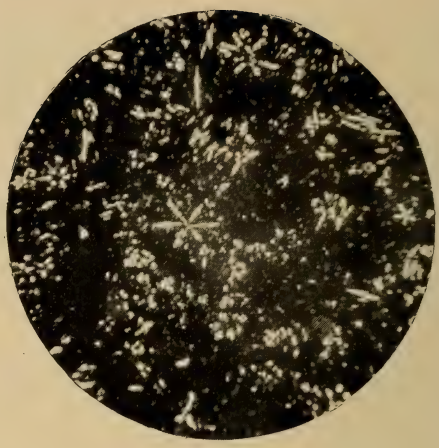
FIG. 4.—STEEL AFTER HEATING TO 1000° C. AND COOLING IN THE FURNACE

per cent., and the variation in elongation is 26 per cent, yet the chemical composition of the four specimens is identical. Why is this?

It is evident that heat treatment has produced an effect upon the physical properties, and the microscope has revealed the fact that a corresponding change has taken place in the structure of the metal. Take a steel rail, for example. When the fractured surface appears coarse to the unaided eye, it will follow that the microstructure is coarse; but when the fracture appears fine, the microstructure may or may not be necessarily fine, though a fine fracture always accompanies a fine microstructure.

Again, examine the two babbitt metals illustrated in Figs. 5 and 6. Both are of the same chemical composition, yet the difference in structure is apparent, and the merest novice in





FIGS. 5 AND 6.—BABBITT METAL SECTIONS, MAGNIFIED 100 DIAMETERS

metallographical study would unhesitatingly pick out the first with its homogeneous structure as the better metal of the two. Briefly, it may be stated that these examples, which are indicative of the results of study in this field, show that the treatment upon which the microstructure depends has an important bearing upon the physical and chemical properties of the metal. It is just as important to know whether a metal is defective because of the unintelligent treatment as from ignorance in proportioning its chemical composition.

The first practical application of microscopy to the study of metals was made to steel, and the fact that this metal plays such an important part in the industrial world to-day gives prime importance to any method that will better its production. Treatment which may or may not have been thermal has an important bearing upon the microstructure. The ultimate requirement is that a material, when manufactured, shall in every respect satisfy the purpose to which it is applied. The maker may provide a metal suited to the requirements, and it may fail in the end through faulty treatment by the user.

The question then arises:—Who is to blame, and what steps shall be taken to apply a remedy? Chemistry alone cannot answer this question, but the microscope in conjunction with it will aid materially. It will reveal whether an ingot or a billet as received was of the proper structure after chemistry has determined the composition. The forging or rolling or other process through which the metal subsequently passes will leave its mark upon the microstructure, and another examination will indicate the defects produced during this process, should defects exist. Every sequential treatment produces an effect upon the microstructure at its corresponding period.

The Kennedy-Morrison process of rolling rails is an example of this. Here advantage is taken of the grain-refining action of rolling steel at a comparatively low temperature, accomplished by retaining the rail for a short time upon a cooling bed before passing it through the finishing rolls. The improvement in quality is so great that in order to put the process in operation at the Edgar Thomson Steel Works, in Pittsburgh, the rail mill was shut down for an extended period in 1900 until apparatus was properly installed to produce the desired results. Other American rail mills, benefiting by this experience, have followed the same course.

In many branches of steel work manufacturers equipped their laboratories with metallographical apparatus. Such firms as the John Cockerill Company, at Seraing, in Belgium; the St. Étienne Steel Works, in France; the Bethlehem Steel Company; the Illinois Steel Com-

pany; the United States Steel Corporation; the Crucible Steel Company, and many other smaller concerns in the United States have adopted the microscope as an aid in securing the best results. Such a list of names is sufficient argument in favour of the use of this instrument in steel works.

It is to be regretted that, due to some unexplainable cause, the application of the microscope to practical use in iron foundry work has not been so rapid and far-reaching as in steel making. There is no apparent reason to believe that cast iron cannot be studied by the aid of microscopy with as promising results as have been reached in the case of steel. The former is found a trifle nearer the carbon side of the freezing-point curve of carbon and iron alloys than is the latter, but it bears a relation to steel similar to that which copper-zinc alloys rich in zinc bear to copper-zinc alloys rich in copper.

Just as much advance has been made in the study of copper alloys by the aid of the microscope as in the study of steel. When a molten mixture of metals cools down to a solid state, crystals of a definite chemical composition separate from the solution and may be seen by the aid of the microscope after properly preparing the specimens. Whether the mixtures be of carbon and iron, copper and tin, or other metal ingredients, they differ in degree of interest only, depending upon the problem in hand, and one can be studied with just as beneficial results to engineering as the others.

The technology of microscopic metallograp hy has been so ably treated heretofore in the publications of several countries that a mere outline of the usual methods and apparatus employed will be sufficient for the present purpose. Any first-class microscope will answer the purpose. It is necessary only to add to the ordinary equipment a vertical illuminator, as the usual methods of illumination where the light is transmitted through the object itself, for obvious reasons, will not answer when opaque objects are to be examined. Artificial light from some source is also required. A gas burner, an incandescent lamp, a Nernst, or an arc lamp with suitable condensing lenses will give satisfactory results. Mount this apparatus on a suitable table, and the investigator is ready for ocular examination of his specimens. Add to this a camera, especially designed to fit the microscope, and he is equipped to record what his previous investigation showed him. In Fig. 7 is shown one arrangement of these appliances. To the right is the lamp, to the left the microscope with camera arranged for vertical manipulation. Between the lamp and microscope are placed two large condensing lenses, a water chamber and Iris diaphragm. This apparatus is capable of such brilliant illumination that the image of the specimen may be thrown directly upon a screen, should several persons desire to make observations at one time.

To prepare the specimen it is necessary first to produce a perfectly plane surface, as free from scratches as possible. The specimen itself may be of any shape and size, limited on one hand by the manipulator's ability to handle it when preparing it, and on the other by the design of the microscope to accommodate it. It may be extremely small, or the full section of a 90-pound rail, for example. Care must be exercised, however, in the selection of the sample, so as to have it represent the average structure of the piece and not some abnormal growth of a local nature, and, in some instances, several specimens must be prepared typifying different parts of the same large piece.

For example, a rail section should be polished and etched. Photographs should be taken at many different points, some around the edge, and some through the centre of the web and flange, and a study of each would be required to determine the effect of temperature upon the microstructure as a whole. In securing samples for several pieces for comparison, it is important to select them from the same relative positions in each case. The samples may be round, square, thick or thin.

The polishing process properly begins with filing, followed by grinding on an

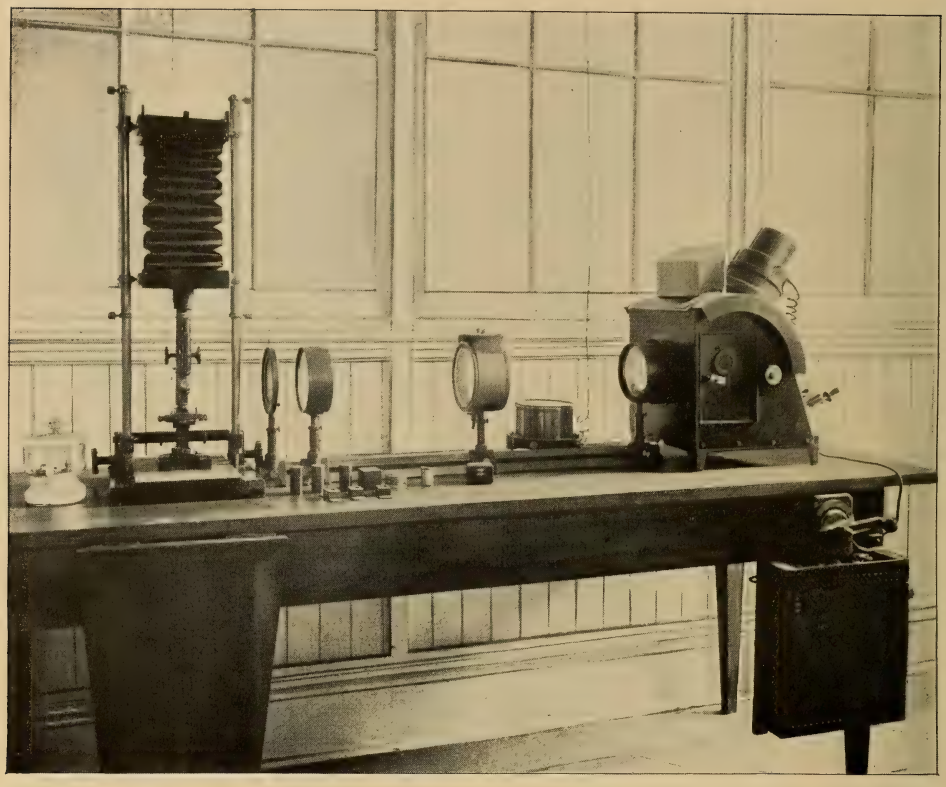


FIG. 7.—A LABORATORY OUTFIT FOR MICROSCOPIC ANALYSIS, AS USED IN THE WESTINGHOUSE WORKS

emery wheel, then successively on wheels covered with cloth filled with emery powder, polishing powder, and rouge. Often the rouge polishing may be omitted.

After polishing, the specimen is etched by the use of suitable reagents, or is "heat tinted," the latter being a differentiation method, depending for its value upon the formation of coloured oxide films, the colours varying with the different chemical constituents in the object examined. It is in etching that the personal factor of the manipulator is most in evidence. Several reagents and methods of their application may be used with equally good results, yet naturally one of these may appeal to the individual more than the others, and that is the one which he will probably use most successfully. In the examination of the etched specimen observation of detail is essential, and the value of the microscopical examination lies in the facility of using such observation to advantage.

Success in photographing the structure comes largely through experience. Conditions differ materially from those existing in ordinary photography; but some skill and patience, coupled with a few trials, will usually suffice to produce good results. Focusing is usually done on a clear glass screen with the aid of a low-power eye-piece, and this method insures very sharp negatives. Exposure may range from one to five seconds, according to the magnification and illumination.

Many details of apparatus and methods enter into the technology of the subject; but while interesting and important, they are not within the scope of this article. It is sufficient here to say that that stage has been reached in the development of the science of metal-

lography at which the time required to complete an examination, including grinding, etching, and photographing, is about half an hour, and is considerably less than that required for the chemical and physical tests. Like the general rules of analytical chemistry, the general methods of metallography may be reduced and simplified as occasion and experience may suggest.

A well-known engineer once said, after listening to a lecture on metallography, that there was a good deal of similarity between bread and steel,—one could combine the right amounts of flour, water, and other ingredients, but a poor cook might spoil the resulting bread. And so it is with any metallic mixture. One may have the component proportions right, and yet, in the making, fail to obtain a product possessing the desired properties. And it is to get around this difficulty that metallography will serve a most useful end.

It can be only after a long and careful study that we can secure full results by the adoption of microscopic methods, and we must keep in mind that the mere aggregation of a large mass of data is far from being all that is required. We cannot expect to apply the knowledge to practical ends immediately; but practical results will be, and have been, obtained through this avenue of scientific research.

FUEL LOSSES IN STEAM PLANTS,

AND HOW TO DETERMINE THEM

By George H. Barrus

FUEL economy in the operation of a steam plant is a subject of wide interest, for almost every factory and industry and almost every building of any size has its steam plant and requires steam for the purpose of heating or power.

Fuel losses are of two kinds,—one, the direct loss, produced by inefficiency of the boiler, and the other, the indirect loss, due to improper use of the steam for the purpose for which it is intended. The first is confined solely to the apparatus in which the steam is generated, and the problem to which it pertains is centered upon a single object. The second relates to a great variety of subjects, depending upon the uses to which the steam is applied, embracing, as it does, the varied industrial operations for which steam is employed in heating, and the great variety of engines and other motive appliances for which steam is used in the production of power.

The first matter of interest which naturally presents itself in regard to this subject is the question of determining whether or not a steam plant is operating at a loss, and, if so, the extent of the loss; and the second question is what course to pursue in overcoming the loss. In answering the first question we are brought at the outset to the only method of determination available, and that is, a performance test of the plant. By this is meant, in the first place, an efficiency trial of the boiler, and, in the second place, an elementary test which determines the quantity of steam used by each piece of apparatus concerned, whether it be a heating coil, an apparatus using steam for boiling, an engine, or a pump, and the efficiency with which each utilises the steam supplied to it.

To make an efficiency trial of the boiler is a comparatively simple matter, and it is one about which so much has been said and written that it requires little explanation. It is sufficient, perhaps, to say that by its means the num-

ber of pounds of water evaporated per pound of coal is ascertained, and thereby the number of heat units absorbed by the water is determined, which is then compared with the calorific value of the fuel found by the calorimeter test, and the desired efficiency expressed as a percentage or proportion.

It is not so easy to devise methods for measuring the steam used by a number of different pieces of apparatus constituting the plant. Considerable ingenuity is sometimes needed in doing this, depending on the circumstances surrounding each particular case. It may be said in general, however, that the measurements can be made by ascertaining the gross quantity consumed by the entire plant, then dropping off one piece of apparatus and determining the quantity used, then dropping off another and ascertaining the quantity used with two thrown off, then dropping off a third, and so on until data have been obtained regarding the whole number, and finally ascertaining the quantity used by each apparatus by subtracting one total from the next one preceding.

In determining the direct fuel loss at the boiler, assuming a hand-fired furnace, a fairly good efficiency result for ordinary cases may be taken as 75 per cent., that is, the number of heat units actually absorbed by the water evaporated is 75 per cent. of the calorific value, or the total heat of combustion, of the fuel. If, by means of the boiler trial, it is found that the efficiency falls below 75 per cent., it may be safe to conclude that the boiler is working at a loss. Taking coal having a calorific value of 14,000 B. T. U. per pound of dry fuel, the efficiency noted applies to an evaporation from and at 212 degrees of 10.87 pounds of water per pound of dry coal. If, therefore, the trial gives a less evaporation with the fuel noted than 10.87 pounds, the indications are, as stated, that the boiler is working at a loss.

Having determined by means of the evaporative test to what extent the boiler is inefficient, the next thing is to locate the cause, or causes, of loss. The most important losses, and those most common, are the losses due to imperfect combustion and to inefficient heating surface. The former is produced by careless handling of the fire and improper admission of air to the furnace, and the latter to faulty arrangement and condition of the heating surfaces. To one who knows by experience the best method of firing any given kind of coal, the character of the combustion can be fairly well judged by viewing the furnace and observing the appearance of the products of combustion and flame issuing from it.

The absolute character of the combustion and the extent to which it is imperfect can be determined only by a chemical analysis of the escaping gases. Such an analysis shows the amount of combustible gas which passes off unburned, and it also shows whether a suitable quantity of air is introduced into the furnace to secure the best results. The analysis, in many cases, proves conclusively whether the method of firing and handling the furnace is the best suited to the fuel used. In the case of a fuel whose characteristics in burning are not well known, it furnishes the best guide available as to how it should be worked. If the efficiency trial shows a low result, other conditions being satisfactory, the gas analysis often provides a means of locating the cause of the loss which, otherwise, it would be difficult to ascertain.

Should it be found from the results of the gas analysis that the quantity of air introduced is too great, it may be due to leakage of air through cracks in the setting, to admission of too large a quantity through the registers in the fire doors, or to the use of too large a percentage of air space in the grate bars. In either case a suitable examination will suggest the proper remedy. If it is found that combustible gas escapes unburned and it is not due to improper firing, it is sometimes caused by the absence of a sufficient quantity of air introduced above the burning fuel. This can often be remedied by simply making perforations in the fire doors, or enlarging those already provided. The use of a suitable automatic stoker, properly handled, secures the most perfect com-

bustion, and this furnishes a means of improving the efficiency beyond the highest that can be obtained where the furnace is hand-fired.

The inefficiency of the heating surface is revealed by excessive temperature of the escaping gases. In many boilers the temperature would be considered excessive if it exceeded 500 degrees F. There are several causes which lead to high flue temperature. One is the crowding of the boiler beyond its economical capacity, and this is so well recognised as to require little comment.

Another, and one which is widely prevalent, is the unclean condition of the fire side of the surfaces, as also the deposit of scale and sediment on the water side. This is self-evident, but yet it is a matter which does not receive the attention that would naturally be expected. The best remedy for such conditions is the more frequent cleaning of the surfaces, whether external or internal, the use of appliances which prevent smoke and soot, and the adoption of means for purifying the water and preventing the formation of scale. The blowing of the soot and ash from the exterior heating surfaces, after no more than twenty-four hours' run, will frequently cause a drop in the temperature of the escaping gases of 50 degrees. A reduction in the temperature of that amount sometimes causes a saving of 5 per cent. of fuel.

The third reason for inefficiency of surface is improper distribution of the surface in the path of the gases, whereby the gases take a short cut to the flue and leave a considerable portion of the surface untouched. This condition is more apt to occur in water-tube boilers than in fire-tube boilers, and the remedy is the rearrangement of the baffling plates so as to compel the gases to cover the surfaces to their fullest extent.

Whatever the efficiency of the heating surfaces of the boiler, there is a limit beyond which it is impossible to reduce the temperature of the escaping gases, for this cannot go below the temperature of the water in the interior of the boiler. At a pressure of 150 pounds this limiting temperature is 366 degrees F. In any case, however, the temperature can be reduced to a great extent, even to a point below the temperature noted, by the employment of a separate heating appliance placed in the flue and receiving the feed water before it reaches the boiler. Such an appliance, which usually goes by the name of economiser, adds much to the efficiency, especially where there are no waste exhaust steam and hot water returns which can be utilised for the preliminary heating.

There is another kind of efficiency determined by the evaporative test, which may be called the commercial efficiency, and that is the cost, instead of the quantity, of fuel used in evaporating a given amount of water. By making a series of tests, using fuel of widely varying prices, and reducing the results to the cost of fuel required for producing a thousand pounds of steam, taking into consideration the cost of firing and handling the various kinds, determination can be made of the cheapest fuel to use. This kind of test often gives results which are of more value to the owner of the plant than the test which merely determines the efficiency based on the evaporation per pound weight.

Having determined the performance of the boiler and the causes of inefficiency which may be going on in the generation of the steam, the next question is to determine the efficiency with which the steam is used after generation. To make the matter clear and specific, it may be well to assume the purposes for which steam in a given plant is employed. Take, for example, the case of a plant in which the principal parts consist of a compound condensing steam engine, an independent, steam-driven air pump for operating the condenser, a steam-driven boiler feed pump, an auxiliary engine for electric lighting, and a steam heating system embracing a number of heating coils which are drained through a trap. Besides the drainage effected by this trap, the system of steam mains connecting the boilers to the engine and the reheater with which the engine is fitted are also provided with traps. The exhaust steam from the pumps is passed through a feed

water heater, from which it escapes to the atmosphere. The quantity of steam used for each of these purposes is ascertained either by the method of differences already mentioned or by some method of direct determination, according as one or the other is best adapted to the situation.

In connection with the test of the main engine, the amount of power developed is ascertained by taking indicator diagrams, and from these is determined the amount of steam consumed per indicated horse power per hour. Whether or not the result thus obtained represents good economy under the conditions of the load which exists, is found by ascertaining from the diagram the weight of "steam accounted for" by the indicator, as it is termed, and comparing it with the actual steam consumption. At ordinary economical loads the difference between the two quantities, when ordinary saturated steam is used and the engine is in good condition, is usually not more than 20 per cent. Should the result of the test show a greater difference than 20 per cent., there is a strong probability that the steam is used wastefully.

One of the most common sources of waste in an engine is leakage of the valves and pistons. If leakage is going on, it can be located by subjecting the various valves and pistons to a leakage test when the engine is at rest, and determining by observation whether the steam blows through. If there are no excessive leakages and the steam consumption per horse-power is still found to be high, revealing thereby a lack of economy, there are a number of causes which may operate in producing this result, and a careful study of the form of the diagram must be made in order to ascertain what these are. Improper setting of the valves which produces a distorted diagram, unsuitable boiler pressure, restricted size of ports and passages, causing loss of pressure during admission and a high back-pressure during the exhaust, too early or too late cut-off, and inefficiency in the action of the condenser, may be mentioned as some of the principal causes of waste.

By a similar procedure the economy with which the auxiliary engine and the pumps consume the steam is ascertained, and the causes of loss, whether leakage of valves and pistons or improper setting of the valves or other improper conditions, are located. When the plant is small and the steam pumps connected with it are comparatively unimportant, it is unnecessary to ascertain the amount of power developed by using the indicator. A simple leakage trial is usually sufficient to determine the main source of loss which is likely to occur.

The principal source of loss as regards the heating coils lies in the means employed for draining the water condensed and for utilising the resulting hot water. Where these are so planned or operated that steam escapes uncondensed through the returns, which may be due either to inefficient working of the trap or to waste from the tank into which the return water discharges, such defects call for a remedy. Whether the steam consumed for heating is excessive or not can be ascertained by calculating from the amount of surface heated, the quantity of steam that should be condensed under the circumstances and comparing it with the quantity found on the test. In any case, having determined the quantity of steam used for this purpose, the question presents itself whether or not the heating cannot be accomplished by exhaust steam derived from the main engine or from the auxiliary engine, and thus economise in the quantity of live steam consumed.

One of the important things shown by the general test of a plant is the efficacy of the feed-water heater. Where exhaust steam is employed, as in the instance cited, and the quantity available is sufficient, the temperature of the water should be raised to a point near 212 degrees. If the temperature is below this point, there is indication that the heater is either too small or that the surfaces are not properly cleaned. If the water is heated to 212 degrees and steam escapes from the heater unused, the steam thus wasted represents a loss. In this case the remedy is to use a portion of the steam for some other purpose.

One method which may be mentioned is to employ a boiler feed pump driven by power instead of by steam. Another is to exhaust one or more of the pumps into the receiver of the engine and utilise the steam for power in the low-pressure cylinder.

The data obtained by the test of steam used up in leakage and condensation of the plant sometimes furnish information of the greatest importance in determining losses, the extent of which can hardly be realised without their aid. That part which is represented by condensation in the steam pipes can readily be calculated and allowed for, and the quantity due solely to leakage losses determined. These are the losses produced by leakage of inefficient steam traps which drain the system of piping and reheater, and leakage of stop-valves which cut off the working part of the plant from the heating mains and from parts of the plant that are not in use, to say nothing of the numberless steam joints involved in the construction of the boilers and piping.

In a plant which is working only a part of the day, say ten or twelve hours, the fires being banked the remaining time, these losses, which may be termed the stand-by losses, are continually going on for the entire twenty-four hours, and they represent a larger percentage of the total fuel consumption than they do where the plant is in operation the whole time. Another loss in plants of this kind which is apt to go on while the fires are banked is by no means insignificant. This is the loss of fuel which results from too much draught being on during that time, either from improperly fitted dampers in the smoke pipe, or from carelessness in handling. The flow of air over the bank of fire produces combustion, the heat from which is expended in merely warming the air, which then passes off through the chimney to waste.

There are many losses in the operation of a steam plant which can best be determined by observation, but in general it may be said that there must be a skillful combination of both observation and test along the lines which are here briefly outlined, if all the wastes are to be located and the greatest efficiency obtained from the fuel.

OIL-FIRED FURNACES

By A. M. Bell, M. Inst. M. E.

THE employment of oil fuel in furnaces of various descriptions is now receiving extended application, and this will doubtless increase as its many advantages become better appreciated. It is not necessary here to enumerate the claims which have been so frequently urged in favour of liquid fuel. Its high calorific value, due to its chemical composition and the fact that the whole of it can be consumed without troublesome residues, makes it an ideal fuel for any heating purpose where a clean fire under perfect control is desired.

Metallurgical operations naturally stand first for consideration among the miscellaneous applications of oil fuel, as they offer every inducement for the satisfactory working of a medium possessing such valuable heat-generating properties. As is well known, of the heat produced in furnaces for melting metal the proportion imparted to and usefully employed in reducing the material is comparatively small and disappointing. To remedy the excessive consumption of fuel and economise in the absorption of heat by unremunerative construction many ingenious arrangements of furnace have been devised; but although the more wasteful features have been eliminated and unceasing efforts have been made to secure the greatest economy, the losses inherent to furnaces designed for the utilisation of solid fuel remain.

With oil fuel the conditions of working are so modified that many of the disadvantages and losses in coal furnace heating are no longer present, and an economy results which guarantees to the

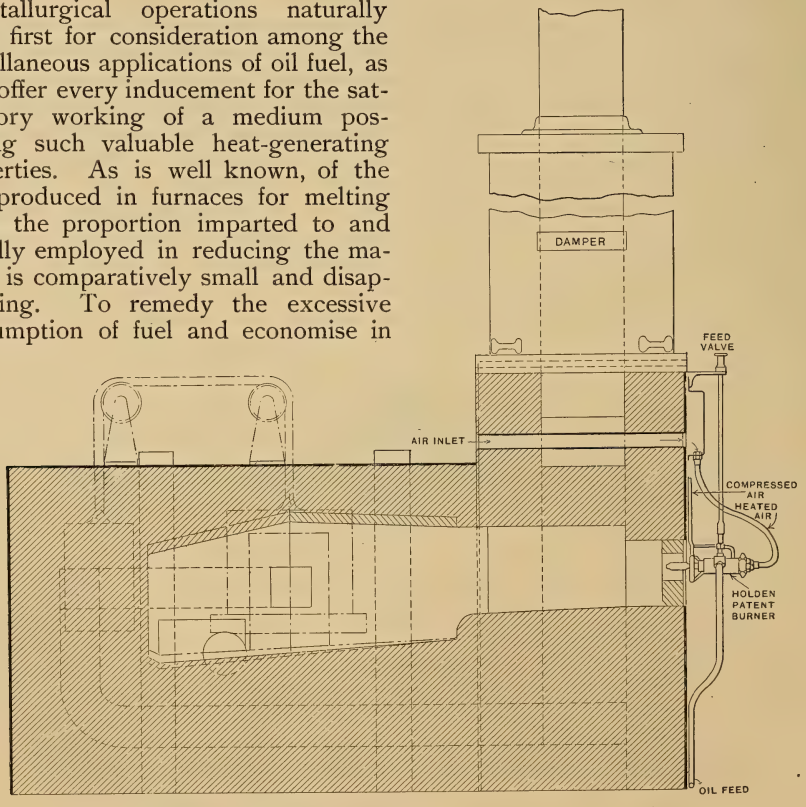


FIG. 1.—AN OIL FUEL BRASS MELTING FURNACE DESIGNED BY JAMES HOLDEN

liquid a value satisfactory as compared to its solid rivals. The price of hard or furnace coke has reached a very high figure in many places, and, in fact, in all those parts of the country remote from the coal fields, whereas the cost of fuel oil is at its lowest in many of those localities. Apart, however, from any direct pecuniary advantage due to cost of fuel required for similar work, the prospect of greatly increasing the output by substituting oil fuel for coal or coke in many industrial operations offers a substantial inducement. This increased

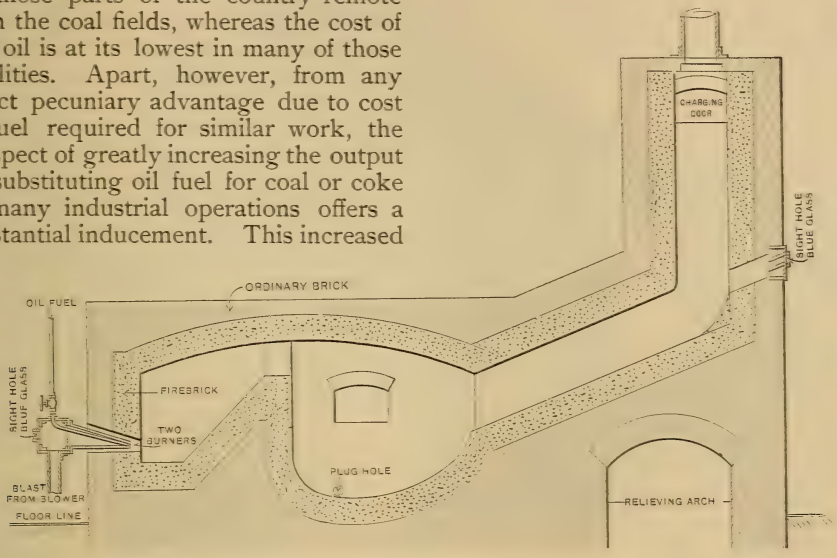


FIG. 2.—A TYPE OF FURNACE MUCH USED IN RUSSIA

production is secured by the easy and exact regulation obtainable, the uniformity of the heat generated, and the concentration of the operative's attention and labour to the work in hand.

The possibility of obtaining a satisfactory liquid fuel in bulk at a price commensurate with its heating value has naturally led to many improvements in the methods of its utilisation for industrial purposes. For steam raising more ingenuity has been devoted to the design of "burners" perhaps than to the construction of the furnaces, although the latter is as important as the former. For heating and melting metals and for various manufacturing operations attention has necessarily been concentrated more on the furnaces required, and some very satisfactory arrangements have been evolved and put into operation. Accepting the heavy Texas oil as the fuel to be used, this possesses a calorific value of about 19,500 B. T. U. per pound, and, owing to its character, is best used with the "spray" method of burning, air being employed as the disintegrating medium when an intense and concentrated heat is required, and steam where a soft and more diffused high temperature is desirable.

For scrap welding or bloom heating, oil fuel is well adapted. The melting and reducing of metals to which oil fuel also has been largely applied possess peculiarly promising features, and the

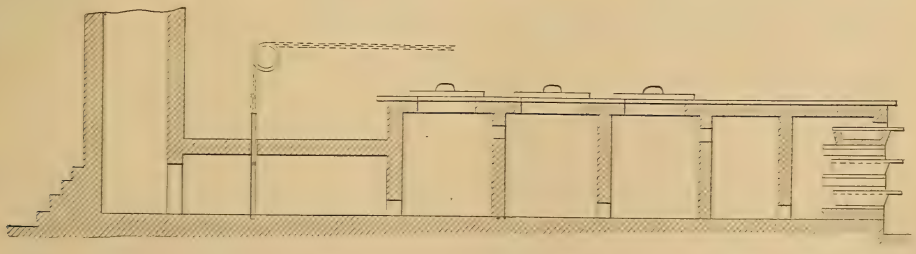


FIG. 3.—A SERIES OF MELTING CHAMBERS HEATED BY GASES FROM AN OIL-FIRED COMBUSTION CHAMBER

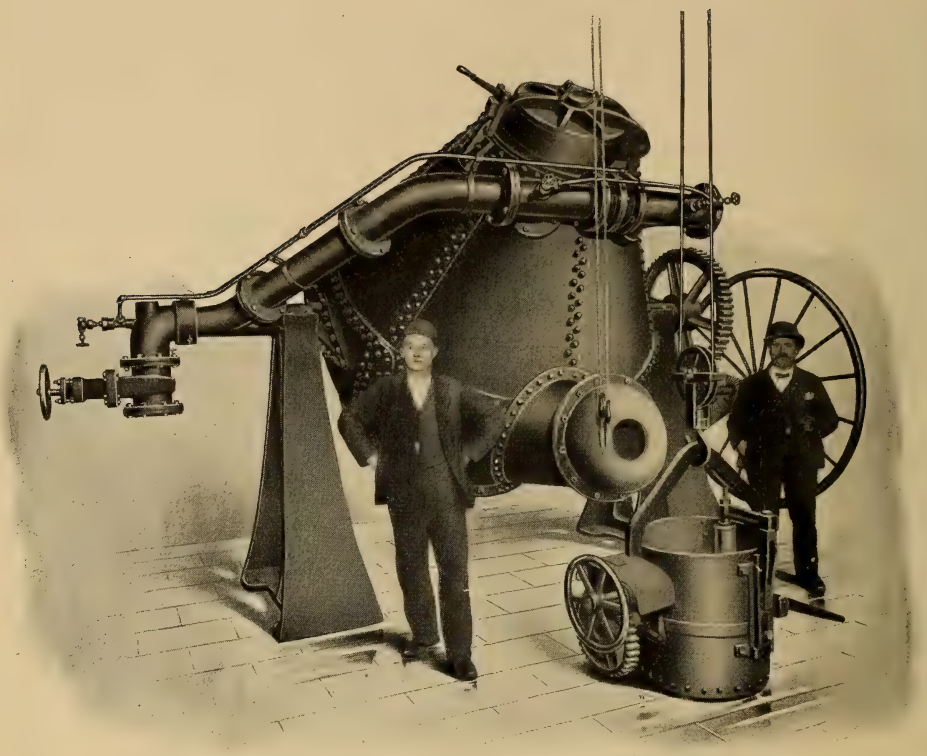


FIG. 4.—A SCHWARTZ MELTING FURNACE. MADE BY THE HAWLEY DOWN-DRAFT FURNACE COMPANY, CHICAGO.

results obtained are convincing of its efficiency for the purpose. In brass foundries a considerable item of expense exists in the provision of the crucibles or "pots" for holding the metal, none of which can well be made available for more than 35 heats, whereas if oil fuel is taken advantage of, the metal can be reduced direct in bulk without the employment of crucibles. Where large castings are required and one peculiar mixture of metal is desired, this is of great importance.

In Fig. 1 a sectional view is given of a brass furnace designed by Mr. James Holden, the locomotive superintendent of the Great Eastern Railway, a pioneer in the use of oil fuel for heating and steam raising. The furnace is in regular use at the Stratford shops, and consists of a combustion and a melting chamber, the oil fuel being sprayed into the former by one of the well-known Holden burners, operated by compressed air at 50 pounds pressure per square inch as the distributing medium. The oil is completely atomised by the "burner," and the finely diffused spray is intimately mixed with the desired amount of atmospheric air. Very exact regulation of the temperature is possible, and a non-oxidising flame is produced at will by manipulation of the supply of compressed air to the annular blower of the burner; waste of metal is thereby prevented to a large extent, but to reduce the loss to a minimum the surface of the molten metal is protected by a film of "clinker," produced from a few handfuls of powdered glass or coal thrown into the furnace when the metal in it has just melted.

A consumption of about 15 pounds of Texas fuel oil per 100 pounds of metal melted is the working record of this furnace. The metal is drawn from a plug hole into the pouring ladle in a manner

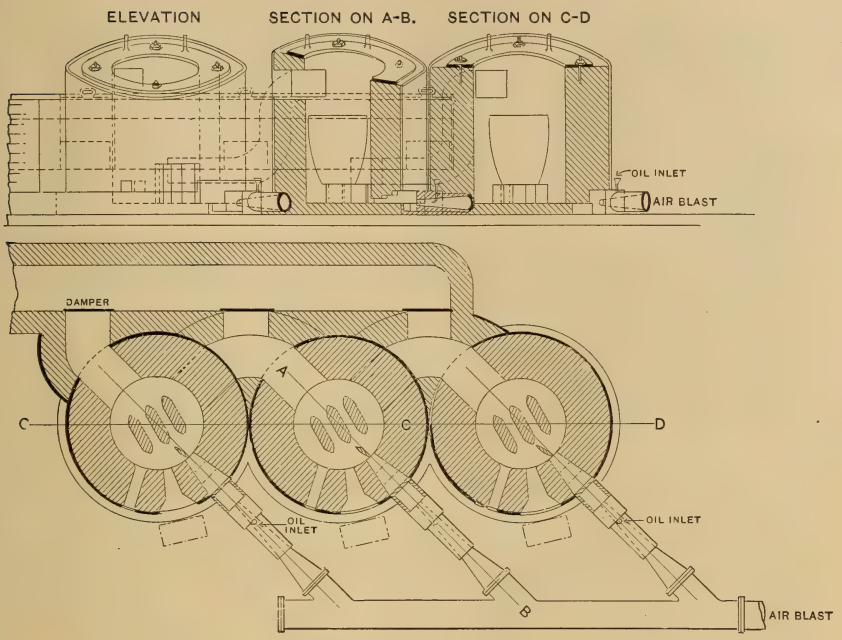


FIG. 5.—A SET OF THREE CRUCIBLE FURNACES HEATED WITH OIL FUEL

similar to that followed with iron, except that the outlet is "stopped" from the inside instead of from the outside, as is customary; this procedure is rendered necessary by the tendency of the brass to cool and block the pouring aperture.

Fig. 2 represents a form of furnace adopted in many Russian establishments and used for melting and refining different metals. In this case the oil fuel is

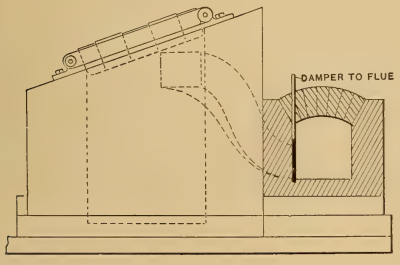


FIG. 6.—ELEVATION OF ONE OF THE FURNACES SHOWN IN FIG. 5

conducted to the expanded end of a pipe arranged inside a case or cone to which an air blast provided by a blower or fan is supplied for spraying, distributing, and promoting its combustion. The metal is introduced through an upper charging door and becomes gradually heated as it falls towards the bed of the melting chamber. It can be drawn off from either side through plug holes operated as described above. In these furnaces an intensified induced draught is employed, in some cases, to promote combustion instead of installing a blower and arranging for blast.

To overcome the losses from oxidisation, unavoidable with the open forms of reverberatory furnaces, some self-contained closed furnaces have recently been introduced for service where room is of value and convenience of handling an important requirement. An example of this type is shown in Fig. 4, representing what is known as the Schwartz furnace. It consists of a globular steel chamber, mounted on trunnions, and lined with fire-brick. Two oil jets, distributed by air blast, are directed to converge to the centre of the chamber, the connections for supply being arranged to pass through the trunnions. The best results have been obtained with these furnaces with oil fed under pressure

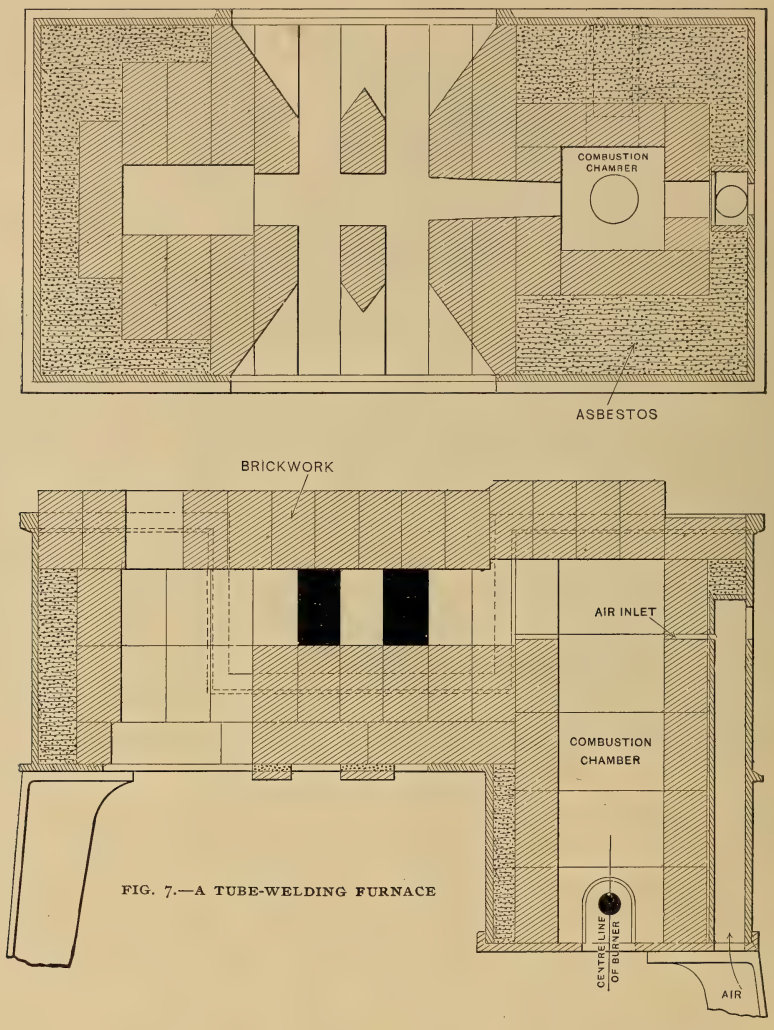


FIG. 7.—A TUBE-WELDING FURNACE

and heated previous to being sprayed from the burners, a pressure of 40 pounds per square inch being found most efficient. The melting chamber is charged through a suitable manhole, and the products of combustion escape from the pouring outlet; the melting is facilitated by causing the chamber to oscillate so that the metal shall be exposed to the whole of the heat-reflecting surface of the globe. Oxidation of the metal is reduced to a minimum by careful regulation of the oil flame and by keeping the metal covered with clinker, as previously explained.

The table on page 79 gives some interesting figures from practice. In melting iron with a Schwartz furnace 500 pounds have been reduced in a 60-inch furnace in thirty minutes and 1500-pound heats secured in an hour. With a 90-inch furnace three tons of metal can be heated at one heat.

Where varying mixtures of metal are required the retention of crucibles is essential, and three arrangements of oil-fired furnaces meeting this condition and utilising the fuel in different ways are illustrated. In Fig. 3 a series of melting or "pot" chambers are heated by the gases passing from a combustion space located at the end of the line and

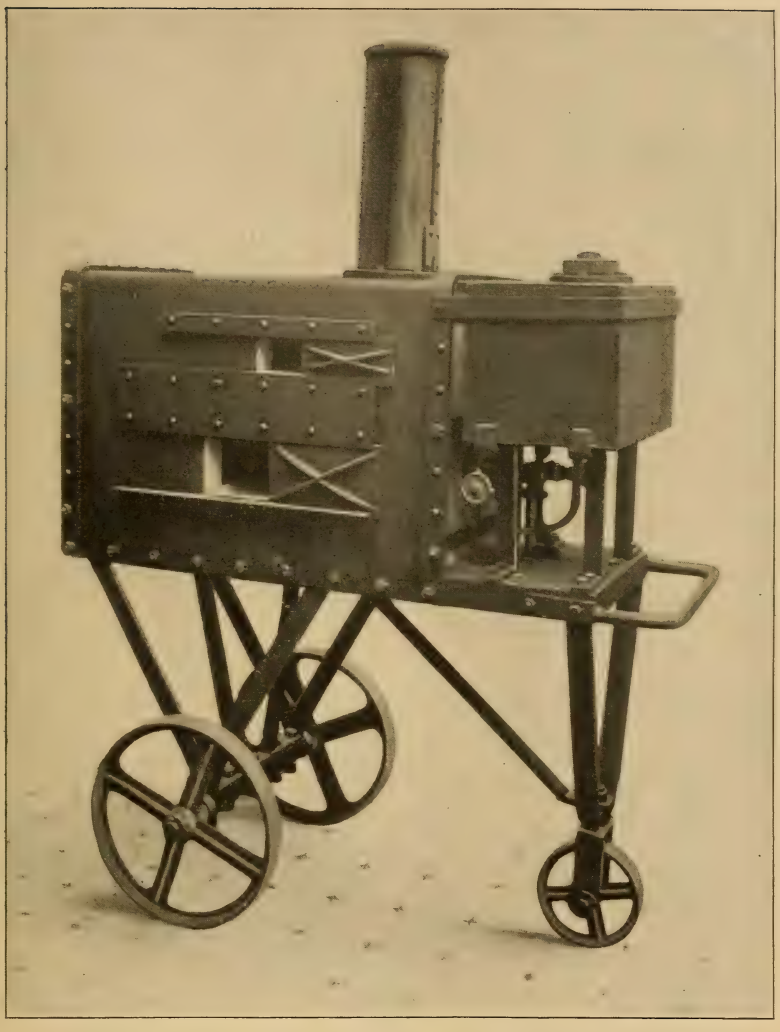


FIG. 8.—AN OIL FIRED RIVET HEATING FURNACE. MADE BY MESSRS. TAITE & CARLTON, LONDON

adjoining the furnace, in which the oil fuel is primarily burned. The liquid runs by gravity from a suitable reservoir to a nest of shallow trays arranged one above another across the open front of the furnace. These trays contain a packing of asbestos, which acts as an absorbing and distributing medium for the oil. As this furnace requires neither air blast nor pressure, it is particularly suited to foundries not provided with power. It is simple and gives a good return, owing to reductions in fuel and labour; further, there is an increased output.

Figs. 5 and 6 show a set of three crucible furnaces heated with oil fuel introduced and sprayed with blower air. A nozzle is allotted to each chamber, and the flame is directed to take a circular course around the base of the crucible (standing on three brick feet) by a small piece of fire-brick forming a deflector. The details of this furnace are well thought out, and its satisfactory working can be vouched for.

The third and last type of crucible furnace which will be mentioned here is that using a spray burner or injector by which the fuel is atomised by steam or compressed air. Fig. 9 illustrates a particularly simple arrangement which enables the conversion of an ordinary coke-fired furnace to be readily undertaken. A Holden burner is placed to face the opening into a small combustion space provided at the base of a stand for the "pot." Compressed air at a pressure of 40-50 pounds per square inch is preferably used for operating the burner.

Among the miscellaneous applications of oil fuel to furnace heating we have tube welding, brazing, annealing, tire setting, etc., and Fig. 7 represents the construction of a very compact and convenient form of furnace adapted to the first-mentioned purpose. A burner, operated by compressed or blower air, is placed vertically at the foot of the combustion chamber, and the heated gases are directed horizontally across the openings provided for the tube ends to be welded. An output of from 70 to 100 tube ends per hour can be secured, —sufficient to keep one welding machine continually supplied.

Another and rapidly increasing use to which oil-fired furnaces are being adapted is rivet heating, and a variety

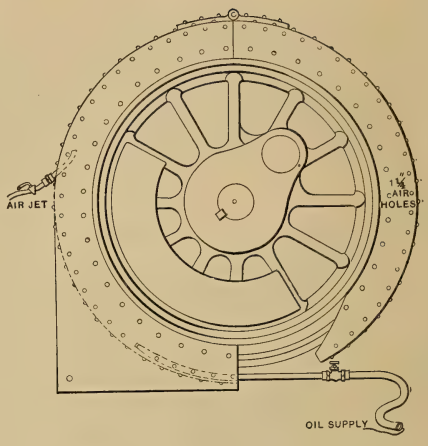


FIG. 10.—A PORTABLE TIRE FURNACE

of compact and portable arrangements for that purpose are now offered. Fig. 8 shows a very successful one. Compressed air is used by preference for the burner. The oil fuel is contained in a small tank immediately over the burner. The rivets are introduced through an open door into the flue, and are gradually fed forward into the lower heating chamber as required. The clean heat imparted and the great number of rivets turned out, are among the chief advantages which this device possesses.

For heating tires in railway shops many oil-fired devices have been intro-

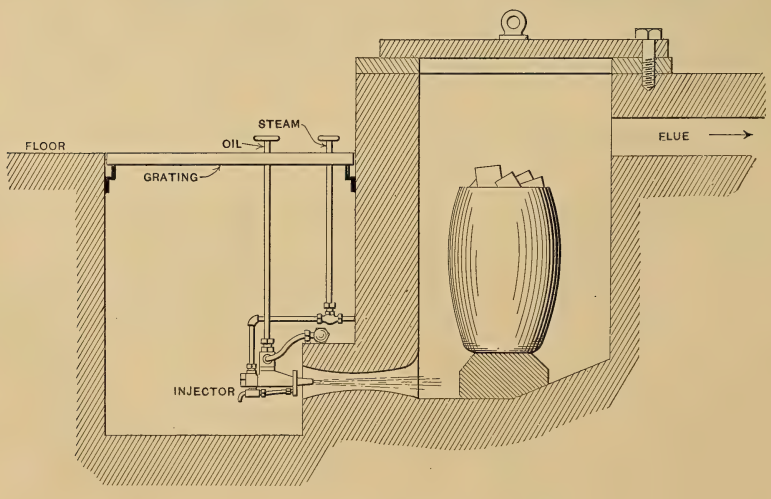


FIG. 9.—ANOTHER FORM OF CRUCIBLE FURNACE

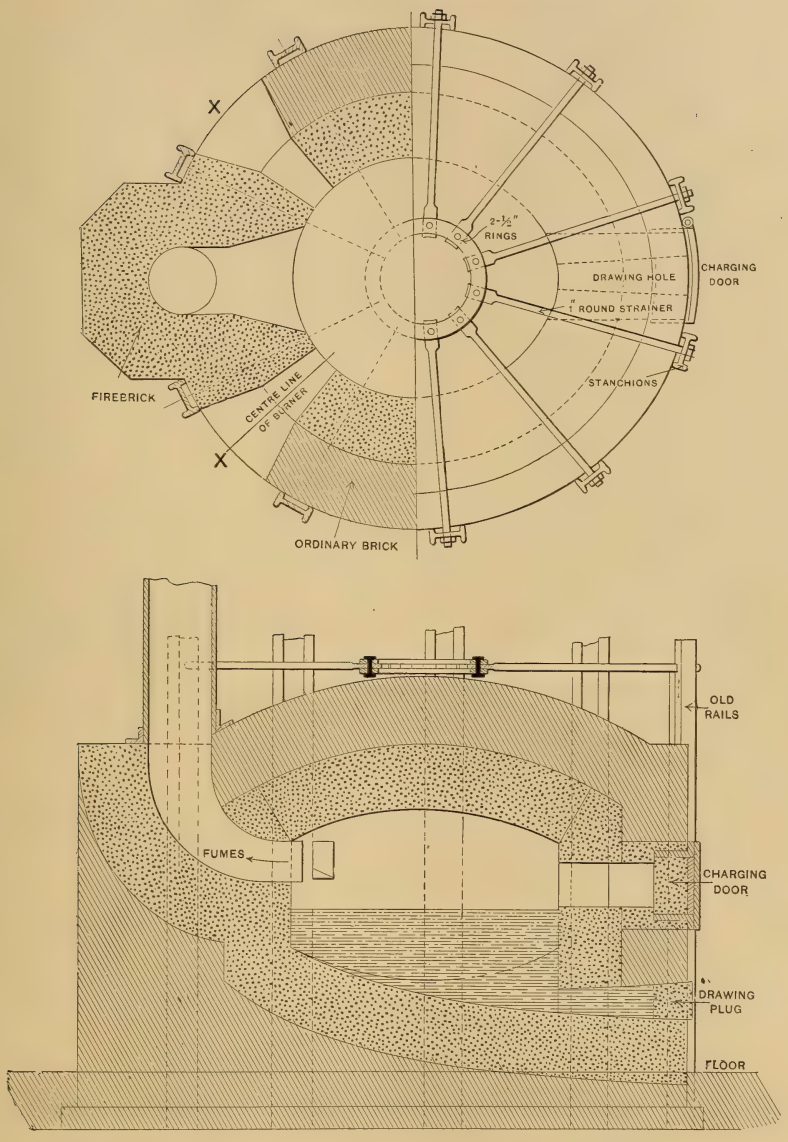


FIG. 11.—A "TANK" GLASS MELTING FURNACE USING OIL AS FUEL

duced. Fig. 10 shows an arrangement possessing considerable merit. It is a portable device which can be brought to operate on a wheel in position; a somewhat similar stationary arrangement can be conveniently attached to the wall of a wheel shop. In both cases a hood or box is provided to form a combustion chamber and to retain and direct the heat as desired. In the portable arrangement shown an air jet carries the flame of the oil jet round the tire. In the fixed arrangement an open-mouthed chamber, lined with fire-brick, forms a miniature furnace to receive that portion of a tire required to be heated.

Before leaving the applications of oil fuel to furnaces its introduction into the glass making industry must be mentioned. For both melting and anneal-

ing, its advantages are marked. In the illustration shown on the preceding page, Fig. 11, a "tank" melting furnace is represented which is heated by the assistance of two burners located at the ports, and directed to spray the oil fuel and consequent flame across the dome-shaped chamber passing over the surface of the "metal." The flue for the effluent gases is provided between the openings, and, by its position, assures a good admixture and distribution of the heat-giving products of combustion prior to their egress to the stack.

For the roasting or baking of carbon filaments for incandescent electric lamps a very high temperature is needed, with exact regulation, and oil fuel is here found to give the most satisfactory results. It is also largely used for heating the ovens employed for different enamelling and japanning processes. It is worth noting also that the difficulties of securing a satisfactory supply of coal or wood fuel in Ceylon having materially increased during late years and oil fuel having been introduced into the country, its application to tea-drying plants has met with very considerable success.

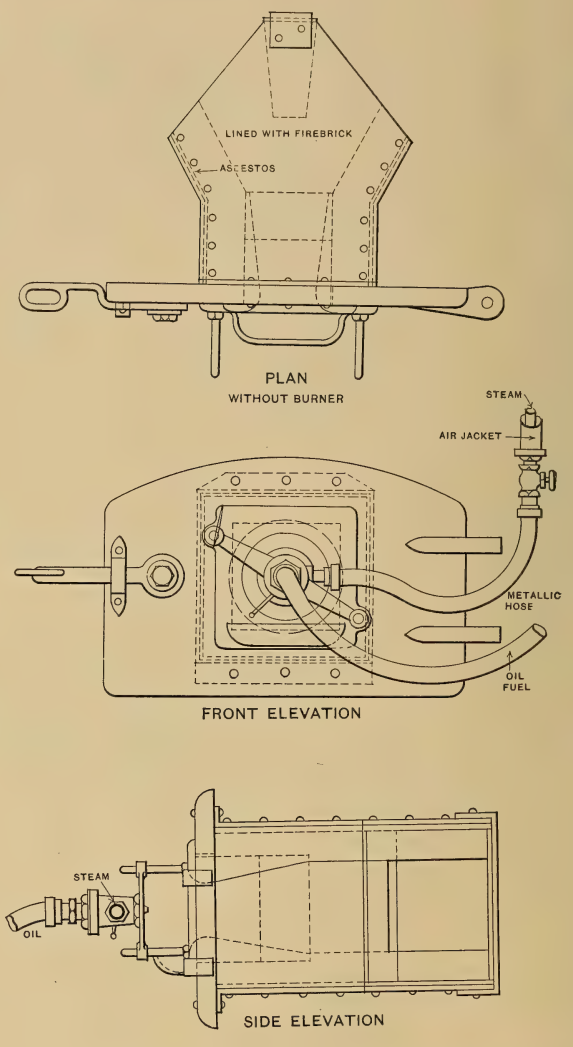


FIG. 12.—A FIRE-LIGHTING ARRANGEMENT FOR LOCOMOTIVES

The last illustration to accompany this article,—Fig. 12,—shows an adaptation of oil fuel for locomotive steam-raising which appeals strongly for employment wherever the smoke nuisance from engines having freshly lighted fires in the large running sheds calls for urgent attention. The British custom of allowing a locomotive to cool off after each day's work and then raising steam afresh when next required, is answerable for a considerable proportion of the objectional smoke, combustion being retarded by the cool furnaces. With the appliance illustrated, a clean, bright fire is kindled at the fire door and the temperature in the upper half of the fire-box is raised to improve the conditions under which the fire is being lighted below. The oil flame rapidly heats the brick arch and the smoke nuisance is removed from this initial operation connected with a locomotive's day's work.

Although the number of applications described in this brief paper is small, and the information imparted limited, it is hoped that sufficient has been written to show that the application of oil fuel

TESTS ON SCHWARTZ METAL-MELTING AND REFINING FURNACES

Test started with the furnace cold at ..... 7.25 A. M.
The furnace was hot at ..... 8.11 A. M.
Time consumed in heating furnace ..... 46 minutes.

Heat No.	Charges.	Lbs.	Time of Charging	Time to Melt. Min.	Poured	Amt. Chgd. Lbs.	Amt. Rec. Lbs.	Shrinkage
1	New copper	201	8.15	53	9.10– 9.16	235	227	3.40 p. c.
	Zinc	21½	----	--	--------	----	----	------
	Lead	7	9.08	--	--------	----	----	------
	Block tin	5½	----	--	--------	----	----	------
2	New copper	300	9.16	60	10.17–10.29	356	353	0.84 p. c.
	Block tin	32	----	--	--------	----	----	------
	Lead	24	10.10	--	--------	----	----	------
3	Light scrap copper	130	10.30	58	11.33-11.39	460	449½	2.28 p. c.
	Old brasses	220	11.00	--	--------	----	----	------
	Brass borings	100	11.20	--	--------	----	----	------
	Lead	10	11.32	--	--------	----	----	------
4	Light scrap copper	159½	11.40	72	11.59–12.06	460	443½	3.58 p. c.
	Old brasses	190½	12.12	--	--------	----	----	------
	Brass borings	100	12.34	--	--------	----	----	------
	Lead	10	12.58	--	--------	----	----	------
5	New copper	300	1.42	56	2.43– 2 56	356	349	1.96 p. c.
	Block tin	32	2.41	--	--------	----	----	------
	Lead	24	----	--	--------	----	----	------
6	New copper	271½	2.57	56	3.54– 4.05	321½	315⅔	1.78 p. c.
	Zinc	30½	----	--	--------	----	----	------
	Lead	10½	3.53	--	--------	----	----	------
	Block tin	9	----	--	--------	----	----	------
7	Old brasses	500	4.08	48	4.57– 5.13	510	500	1.96 p. c.
	Lead	10	4.54	--	--------	----	----	------

Total amount charged ..... 2698½ lbs.
Total amount received ..... 2637¾ "
Total shrinkage ..... 60¾ " or 2.25 p. c.

OIL

	Gallons	Pounds
Total amount used	65.83	483.85
Amount used in heating furnace	9.50	59.82
Amount used in melting	56.33	414.03
Amount per hundred lbs. of metal used	2.44	17.93

From heat No. 12, 5 and 6 sample test bars were poured and drilling from same were analysed. Test bars were not poured from the other three heats on account of scrap having been used in the mixtures. The analyses of the test bars are as follows:

Heat No.	1	2	5	6
Per cent. Copper, calculated from mixture	85.53	84.27	84.27	84.45
" Tin " " "	2.34	8.99	8.99	2.80
" Lead " " "	2.98	6.74	6.74	3.27
" Zinc " " "	9.15	----	----	9.48
" Copper, actual, calculated	85.36	83.57	83.81	84.53
" Tin, calculated	2.58	9.28	9.08	3.21
" Lead "	2.86	8 55	6.19	2.78
" Zinc "	8.15	----	----	8.35

to furnace heating is a subject of considerable import even now, and will doubtless become still more important in the near future. The devices shown in the several illustrations accompanying these remarks are all in successful use,—not merely experimental apparatus,—and thus are of direct practical significance.

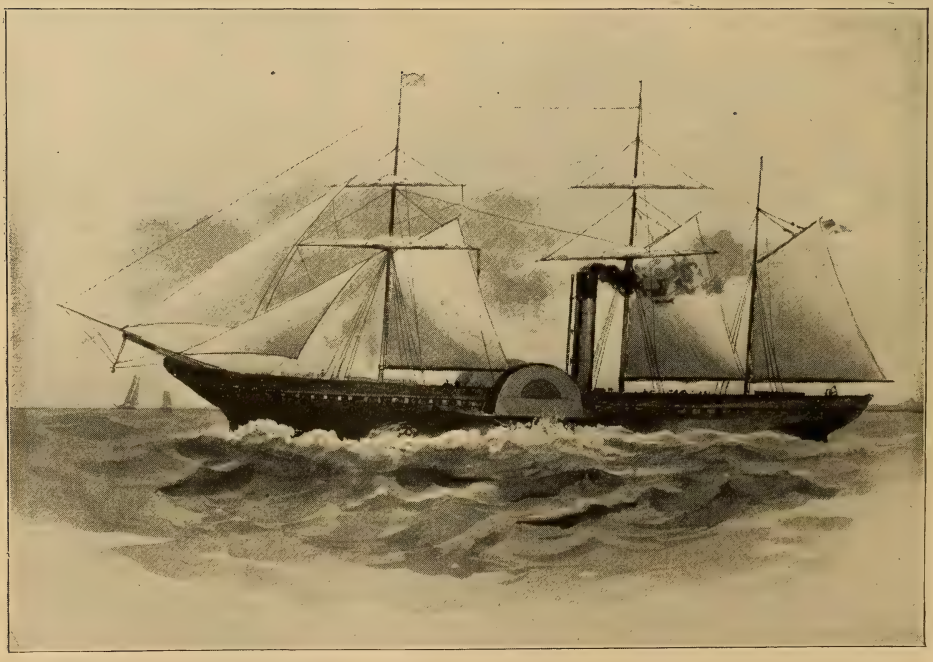
THE STEAMSHIP OF THE FUTURE

GREATER SAFETY, COMFORT, SIZE, AND SPEED

By Stephen P. M. Tasker

LET us consider for a moment the matter of safety! What can be done to increase it? Something must be done, judging from the unusually large number of ships that have lately sunk or met with accidents. Ships can be made, and are, to a small degree, unsinkable; but there is no reason why all steamers, and especially those carrying human lives, should ever sink from ordinary collision with boats or shore. They can be made unsinkable only by watertight bulkheads, and by watertight ones the writer means bulkheads with absolutely no doors in them. These, probably, will be said to be not practical; but they are, and steamships of the present day and size can get along without openings of any kind in their bulkheads up to a deck or so above the water-line. Cargo spaces can be kept separate from one another, passengers of the different classes can be kept apart, and also coal, stores, and machinery. A door is not needed between the boiler and engine rooms, and this particular door is the most dangerous of all, not only because it connects the largest compartments, but also because it may lead to serious results to both by the flooding of steam or water.

The propelling power will be divided



THE FIRST CUNARD LINE STEAMER "BRITANNIA," 1840. LENGTH, 207 FEET; 403 HORSE-POWER; 1139 TONS. TIME OF FIRST TRIP FROM LIVERPOOL TO BOSTON, 14 DAYS AND 8 HOURS

THE TURBINE STEAMER "QUEEN ALEXANDRA." BUILT FOR SERVICE ON THE CLYDE, SCOTLAND, BY MESSRS. WILLIAM DENNY & BROS., DUMBARTON, AND ENGINED BY THE PARSONS MARINE STEAM TURBINE CO., LTD., WALLSEND-ON-TYNE. HER MACHINERY IS SIMILAR TO THAT OF THE "KING EDWARD," SHOWN ON PAGE 84, BUT MORE POWERFUL. LENGTH, 270 FEET; BEAM, 32 FEET; TRIAL TRIP SPEED, 21.625 KNOTS

THE WHITE STAR LINE STEAMER "BRITANNIC," RECENTLY BROKEN UP AND SOLD AS SCRAP IRON. LENGTH, 455 FEET; BREADTH 45 FEET; DEPTH, 33 FEET. BUILT IN 1874. IN HER LONG SERVICE IT IS SAID THAT SHE NEVER LOST A DAY FROM ACCIDENT OR DISABILITY, WORKING CONTINUOUSLY WITH THE SAME ENGINES AND BOILERS WITH WHICH SHE WAS ORIGINALLY EQUIPPED. SHE WAS THE FIRST LINER TO MAKE THE TRIP FROM QUEENSTOWN TO SANDY HOOK IN LESS THAN EIGHT DAYS

into two or more units, each with its separate compartment. The boilers, too, will be divided up, so that in case of collision and consequent flooding the only result will be loss of speed, but never, or rarely, total disablement. Whatever communication may be necessary can be carried on over the bulkhead, and whilst this may prove somewhat inconvenient to the crew, it is not worth taking into account as compared with the great risk of having openings below. It may be admitted that ships are saved even with these doors; but now and then one goes down, and it is just this one that makes it, or should make it, against the law to cut doors below the water-line.

Side lights could be put in to see how things are going on, and speaking holes, too, with automatic closing devices. It would not take much of a leak to fill a compartment. The bursting of, or injury to, the main injection valve would do it very quickly. Some of the so-called watertight doors work from the bridge, but there are occasions when there is no time to call and explain to that quarter. Leave the doors out, and in some cases, as in the shaft alley, have a small, easily closed door or self-closing manhole, but in the main division no door whatever. All bulkheads should be thoroughly tested and made amply strong for a possible flooding. Some of those put on merchant steamers, so-called watertight, have been known, when compartments were filled, to swell out and leak and even collapse. Large and well-arranged escapes from every hold should be fitted to boat decks. There should be a couple at least from each engine and boiler room, from shaft alleys and every other part of the ship.

The life boat question is one that may be examined into with profit. There are numerous devices on the market much better than the present cumbersome arrangements on the average steamer. It takes too many men too long a time to get one of the boats over and down, and the crew, moreover, are often the only ones able to work the life boats. This is not as it should be. It ought to be possible for anyone to do the launching. If a ship is going down

or is in great danger, there are not enough of the crew available to operate all the boats nor enough boats for all of the passengers. Boat drills are all right, but in time of panic one cannot depend on this systematic launching of the boats.

Invariably the crew get away first, and generally a very few of the boats are gotten off in time. Let us have more boats and easily lowered ones,—the cradle removed, and then this heavy load swung and lowered, and this, too, at a time of accident, with the ship going down? We meet an objection in many so-called improvements, and that is the complication which offsets the improvement, if, indeed, there be any. Simplicity is a remedy for most defects as we find them. We do not want complication anywhere.

There is another matter of which

THE CUNARD LINER "UMBRIA." LENGTH, 500 FEET; BEAM, 57 FEET. A GOOD EXAMPLE OF THE BEST PRACTICE OF THE YEAR 1884. AVERAGE SPEED DURING FASTEST PASSAGE, 19.76 KNOTS, MAKING THE RUN FROM QUEENSTOWN TO NEW YORK IN 5 DAYS, 22 HOURS, AND 7 MINUTES

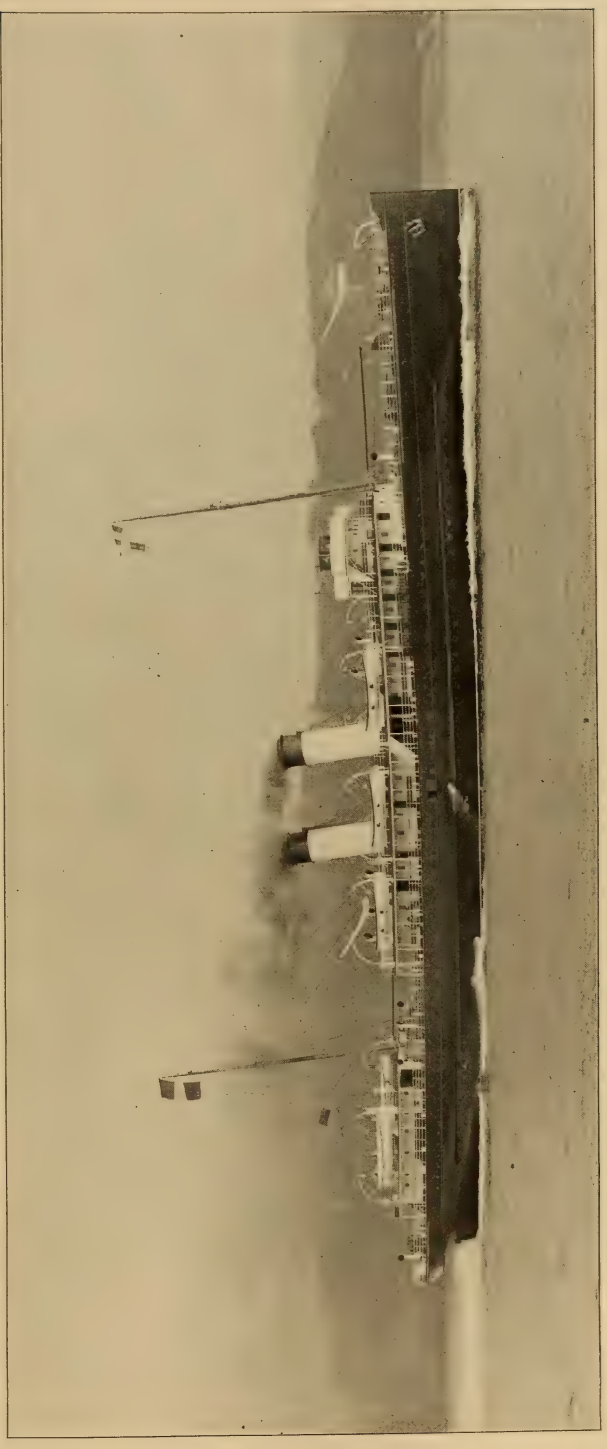
good, practical devices that do not require almost a winch to operate. Let some be self-launching, non-collapsible, and non-sinkable, and keep them provisioned in fact. Did you ever think of the length of time it would take to get the canvas covering off, bread and water stored, the boat hoisted and tried, first bow and then stern, till she could be swung out clear of the davits, to have pressing needs have been demonstrated by the burning of a number of large steamships, and that is, port holes large enough for people to get out of. If round port holes cannot be made large enough for this, there should be a regular size set in a square port that can be easily opened in emergencies, and a wrench, or whatever tool may be necessary for opening, handy in each room.

THE "KING EDWARD." BUILT IN 1901 FOR SERVICE ON THE CLYDE, SCOTLAND, BY MESSRS. WILLIAM DENNY & BROS., DUMBARTON, AND ENGINED BY THE PARSONS MARINE STEAM TURBINE CO., LTD., WALLSEND-ON-TYNE. THE FIRST PASSENGER VESSEL PROPELLED BY STEAM TURBINES. LENGTH, 250 FEET; BEAM, 30 FEET; SPEED ON TRIAL TRIP, 20.48 KNOTS. THERE ARE THREE TURBINES, ONE HIGH-PRESSURE ON A CENTER SHAFT, AND TWO LOW-PRESSURE, WORKING IN PARALLEL, DRIVING THE SIDE SHAFTS. IN THE EXHAUST CASING OF EACH OF THE LOW-PRESSURE TURBINES IS PLACED THE REVERSING TURBINE

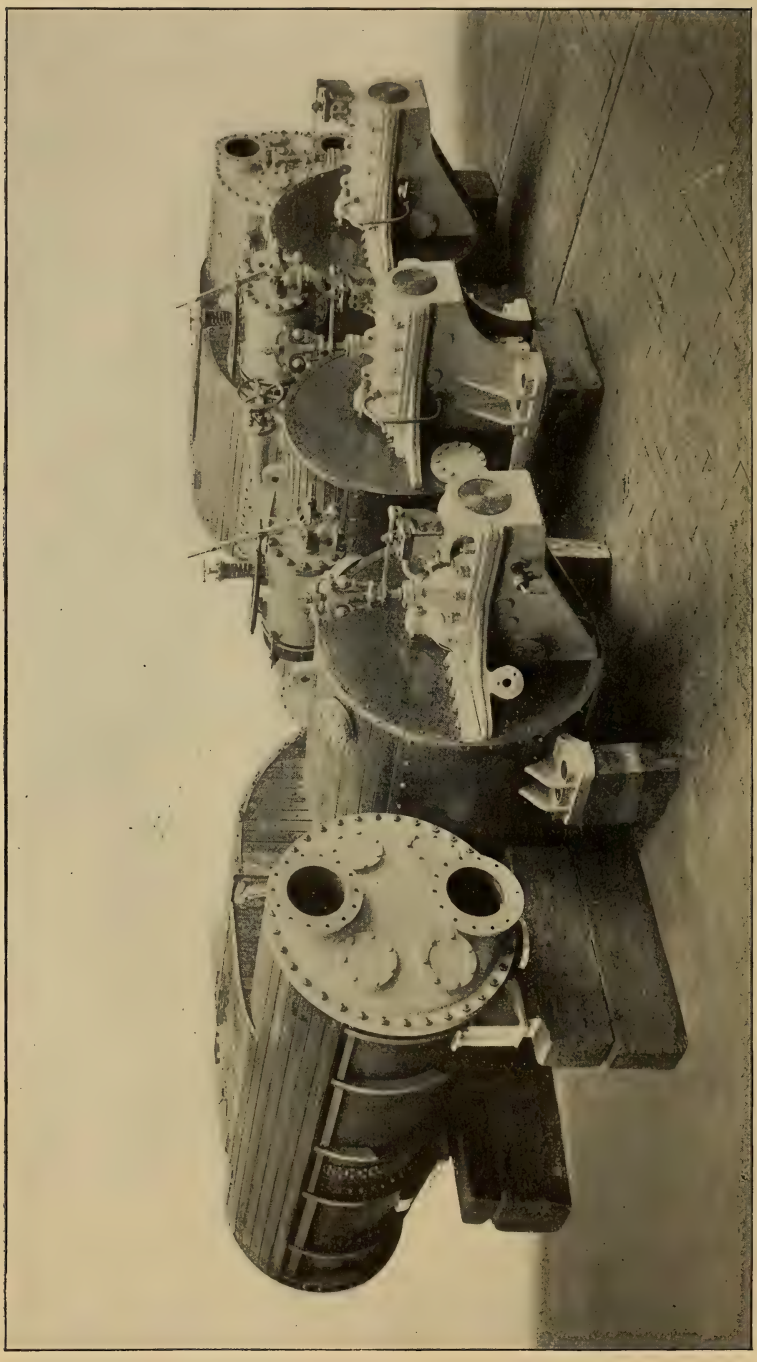
There would be no time to hunt help or stewards in case of fire or sinking.

Under the head of safety is the place to include the subject of wireless telegraphy, and although the writer would put non-sinkability as of first importance, means of communicating with the shore when in danger is an invention of the greatest benefit the world has ever known; it is an invention for safety that stands pre-eminently first. With it help can be summoned in cases of danger, the exact location and condition of the ship can be made known, and this can be kept up until the last minute if need be. Enough credit cannot be given to the inventors of wireless telegraphy. There should be an outfit on board every ship, whether steam or sail.

In the matter of comfort afloat the principal source of annoyance to passengers is the vibration of the ship and poor ventilation. The turbine will overcome much of the former, besides making the ship cooler



THE DOVER-CALAIS TURBINE STEAMER "QUEEN." BUILT FOR THE SOUTH EASTERN & CHATHAM RAILWAY COMPANY'S CHANNEL SERVICE, BY MESSRS. WILLIAM DENNY & BROS., DUMBARTON. LENGTH, 310 FEET; BEAM, 40 FEET; TRIAL TRIP SPEED, 21.73 KNOTS. THE TURBINES ON THIS SHIP WERE DESIGNED TO DEVELOP 8000 H. P.



THE TURBINE MACHINERY OF THE YACHT "EMERALD" WAS BUILT BY THE PARSONS MARINE STEAM TURBINE CO., LTD., WALLSEND-ON-TYNE. THERE IS ONLY ONE PROPELLER ON EACH OF THE THREE SHAFTS

THE TURBINE YACHT "EMERALD," BUILT FOR SIR CHRISTOPHER FURNESS, M. P., BY MESSRS. ALEXANDER STEPHENS & SONS, LTD., GLASGOW, AND NOW OWNED BY GEORGE GOULD, OF NEW YORK. THE FIRST VESSEL PROPELLED BY TURBINES TO CROSS THE ATLANTIC

around the engine room, and ships are being built larger and stiffer. There are a number of staterooms on large vessels, located over and around the engine and boiler rooms, that are undesirable to say the least, on account of the heat. The ship must be better insulated, and the heat must be gotten rid of more easily or saved entirely in ways that the advance of engineering science will point out. Ventilation must be better.

In the matter of speed some believe in the intermediate type of vessel and say "no more speed is wanted." Speed, however, has been increasing steadily, and no one can predict to what point it will be carried. The *Kaiser Wilhelm II.*, of the North German Lloyd, and the *Deutschland*, of the Hamburg-American Line, represent the limit at the present. We shall have speedier ships, of course; but whether they will be fast or slow, they will eventually be driven by turbines. These motors will as surely replace the reciprocating engine as the screw has replaced the paddle. What is wanted is a slow-speed, economical turbine of great power, and we shall have it,—in fact, we are getting it now. Everything is to the advantage of this form of engine, —low centre of gravity, few parts, speed, reduced cost of operation, considering engine room force, and less vibration. The last is not only a source of annoyance to passengers, but also dangerous. The constant vibration is bad for the hull and rivets, and for the engine, too.

Amongst the greatest advantages of the turbine is the saving of heat, which, of course, means coal; but it means also a cooler engine room, and this, in turn, cooler cabins. A steam turbine can be almost perfectly insulated; there are but a few bearings, and they should be of the roller type. The thrust bearing, too, should be a roller bearing. It is an unsafe prediction for anyone to say that certain machinery has reached its limit of efficiency, but we are probably

pretty nearly correct in not expecting much further improvement in a crank engine. There is a limit to piston speed, especially as we increase the weight of the moving parts, with many wearing surfaces, and high centres with cylinders well above the water-line. These defects and many more are covered by the turbine, and we shall soon see it in general use.

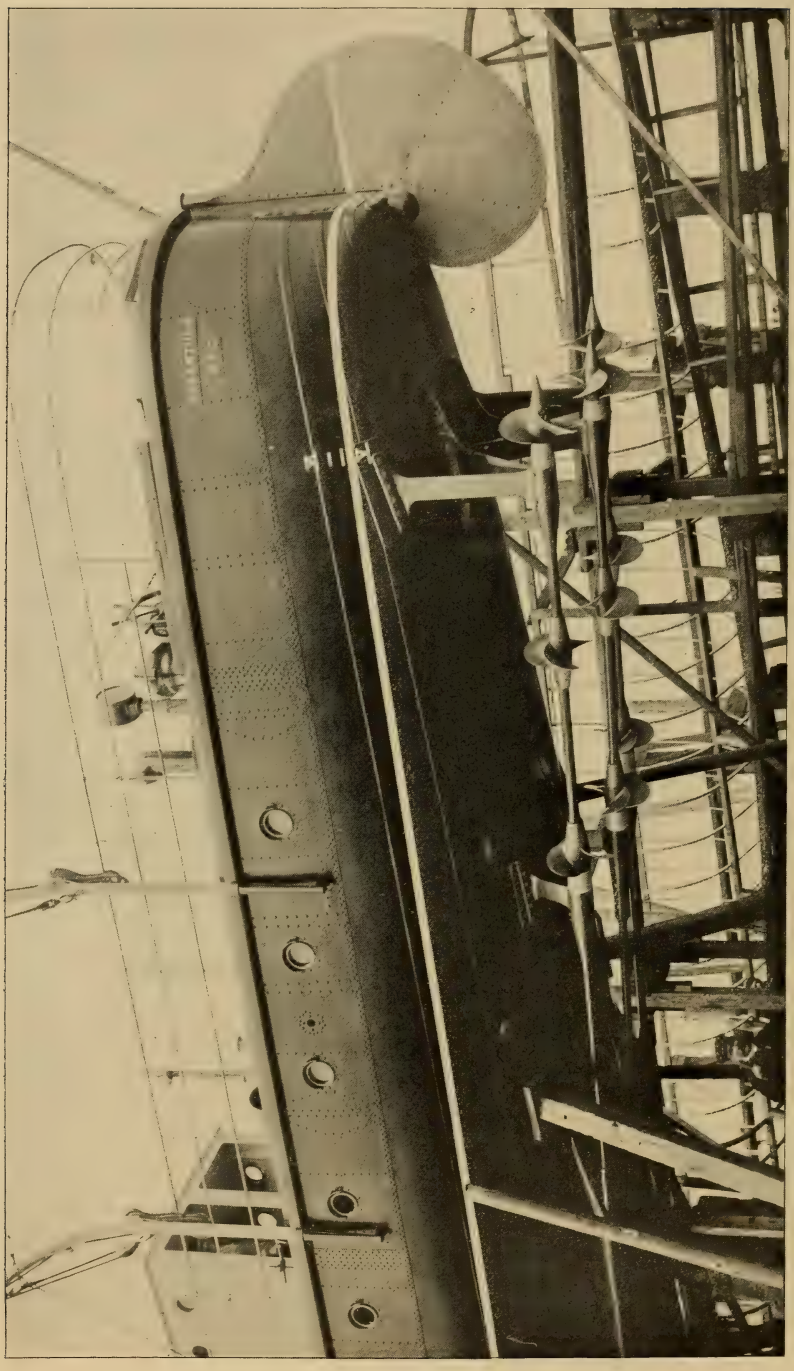
The fact that one of the large shipbuilding companies in the United States

THE TURBINE YACHT "TARANTULA." BUILT BY MESSRS. YARROW & CO., LTD., POPLAR, LONDON. OWNED BY W. K. VANDERBILT. LENGTH, 152 FEET; BEAM, 15 FEET; DISPLACEMENT, 150 TONS; TRIAL TRIP SPEED, 26.75 KNOTS

offered to equip a naval cruiser with turbines is suggestive. The few bearings that a turbine would have will be rollers, and the efficiency of a motor with but a few wearing surfaces, and these of such an anti-friction kind as rollers, ought to be benefits of no mean order. The turbines would have no surface to adjust, no wear of any account, could be well balanced, and would work as economically, if not more so, in point of fuel, as a reciprocating engine.

Regarding capacity and size, the writer believes we shall see ships getting larger and larger, although there must be a limit. Draught will be the principal factor to check abnormal dimensions, as there must be a certain relation of draught to beam and draught to length. Taking the steamship *Umbria*, built in 1884, as a good example of the best practice of that time, and the *Kaiser Wilhelm II.*, as the highest type of to-day, we find there has been an increase of about 10.6 feet a year in length and 0.184 knots an hour in speed. This rate of increase, while it will not keep up indefinitely, will be maintained for a certain length of time. All develop-

A DRY DOCK STERN VIEW OF THE "TARANTULA"



ANOTHER DRY DOCK VIEW OF THE "TARANTULA." AS ORIGINALLY CONSTRUCTED AND HERE SHOWN, SHE CARRIED NINE PROPELLERS, THREE ON EACH SHAFT, BUT LATER THREE OF THESE WERE REMOVED, RESULTING IN AN INCREASE OF SPEED

ments have progressed with great bounds for a few years, and then have settled down to a practical basis. This settling-down period has not yet arrived in the steamship world, as the ever-increasing size and speed of ships will show. Referring again to the *Umbria* and the *Kaiser Wilhelm II.*, the table in the adjoining column is of interest.

We can now approximate the size of a steamer about on these lines and settle on a 35-foot draught. This is not too much with a 40-foot dredged harbour, and it may go even further. With a 35-foot draught, then, a ratio of length to draught of, say, 25, and a ratio of length to beam of 10, and with the same block coefficient as the *Kaiser Wilhelm II.*, we would get 875 feet length of load water-line, 87.5 feet beam, 47,600 tons displacement, and, with an Admiralty coefficient of 287, we would need about 72,000 I. H. P. for a sea speed of 25 knots. This horse-power, the writer believes, will be obtained with turbines, and a ship of this size we shall live to see.

	S. S. Umbria.	*S. S. Kaiser William II.*
Built	1884	1893
Length on load water line	500 ft.	702 ft.
Beam	57 ft.	72 ft.
Draught	22.5	29.5
Displacement	9,860 tons	26,500 tons
Block coefficient	0.538	0.622
Admiralty "	263	287
Length ÷ Beam	8.77	9.74
Length ÷ Draught	22.2	23.8
Steam pressure	110 lbs.	213 lbs.
Piston speed	840 ft. per m.	944 ft. per m.
Speed	20 knots	23.5 knots
I. H. P.	13,920	40,000

SAMUEL PIERPONT LANGLEY

Astronomer, Physicist, and Secretary of the Smithsonian Institution

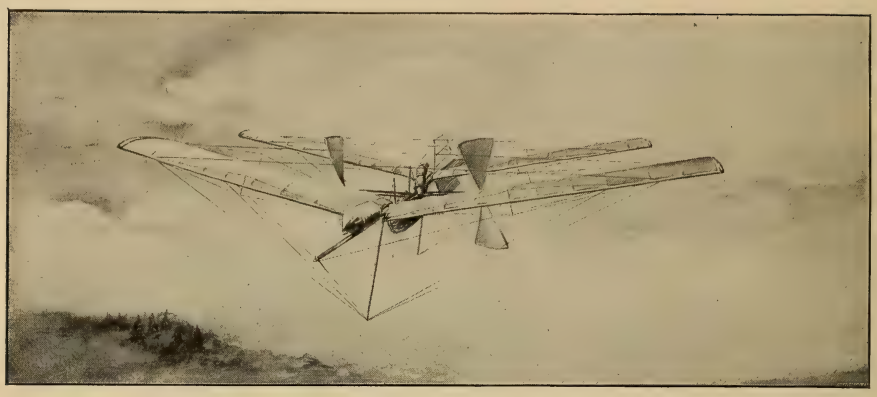
A BIOGRAPHICAL SKETCH

By Dr. Cyrus Adler

UP to the thirtieth year of his life, after an education at the Boston High School, Samuel Pierpont Langley practised civil engineering and architecture, devoting himself privately to the study of astronomy. From youth, in fact, he had a profound interest in the study of astronomy, which eventually shaped the character of his life work.

In 1865, at the age of thirty-one years, after extended European travel, in which he visited foreign observatories and learned institutions, he decided to devote himself to scientific pursuits. In that year he became an assistant at the Harvard College Observatory; in 1866 assistant professor in mathematics at the United States Naval Academy at Annapolis, and at the end of that year, director of the Allegheny Observatory at Pittsburgh. There he laboured twenty years. He found the observatory virtually without any equipment and the Western University of Pennsylvania without funds to provide it, and accordingly inaugurated the system of supplying standard time to the railroads and other places as far east as the Atlantic seaboard and as far west as the Great Lakes, thus securing the funds which rendered it possible to secure an adequate equipment for the observatory. This furnishing of time by telegraph, never before attempted on an extended scale, resulted in the system of standard time now universal throughout the United States.

In 1869 he took charge of one of the United States Government surveying parties in observing the total solar eclipse of August 9, in Kentucky; in the winter of 1870 he accompanied a Government eclipse expedition to Jerez



THE LANGLEY FLYING MACHINE

de la Frontera, in Spain; in 1878 he took charge of a party sent out by the Government to witness the total eclipse of that year from Pike's Peak; in 1881, of an expedition for the United States Signal Service to the Sierras of California, to study the solar constant; and in 1900, of a Smithsonian party to observe the total eclipse of that year.

His astronomical work has been devoted almost exclusively to the study of the sun, for which he has invented numerous new devices, notably the bolometer, a most delicate instrument for measuring heat, which in its modern form registers much less than the millionth part of a degree Centigrade. He has made most accurate observations and drawings of sun-spots, and has devoted much of his scientific life to the great problems of the solar constant and the energy spectrum of the sun. He has also studied the energy spectrum of the moon, whose heat has been analysed in minute detail in the lunar spectrum by the aid of the bolometer.

His bolometric investigation, extending over many years and devoted to the study of the infra-red or invisible spectrum, is the most considerable work that has been done in this line. It has resulted in the discrimination and actual determination by their temperature alone of over 700 lines, extending the knowledge of the spectrum to a distance nearly eight times that known to Newton.

From boyhood Mr. Langley was interested in aerial flight. This subject he took up seriously in 1889, and in 1891 published his "Experiments in Aerodynamics," followd in 1893 by the "Internal Work of the Wind." Both of these papers are based upon numerous experiments which had their fruition in 1896, when, for the first time in history, aerodomes, that is, flying machines, wholly without gas or any supporting power but that of their steam engines, made several flights of over half a mile each, which have since been repeated, thus demonstrating by actual experiment that a body nearly a thousand times heavier than the air it displaces can be driven through and thus sustained by it. He is still engaged in these experiments, which are being conducted on a more extended scale than heretofore.

In 1887 he became secretary of the Smithsonian Institution, at Washington, D. C., which has under its charge various agencies of widely diversified scientific interests. At the time of his assuming charge of the Institution its bureaus consisted of the National Museum, the Bureau of American Ethnology and the International Exchanges. To these there have been added, largely by his exertions, the Astrophysical Observatory and the National Zoological Park.

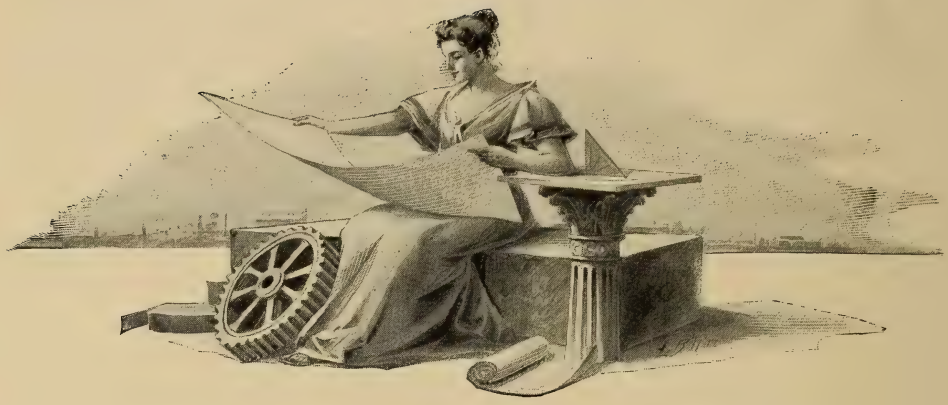
Mr. Langley's published writings include over one hundred titles. In addition to many technical papers and works

of value, he has written "The New Astronomy," and delivered several notable addresses, which, in addition to scientific accuracy, possess great literary charm. This is especially true of his "New Astronomy," which, from the literary point of view alone, is one of the most notable scientific works ever produced in the United States.

Besides his work in his own specialties Mr. Langley has a deep interest in the fine arts, in general philosophy and in literature, presenting, in fact, the not too common spectacle of a scientific specialist whose interests extend over the whole domain of learning and of literature and art.

He is a vice-president of the American Philosophical Society; a foreign member of the Royal Society of London; a correspondent of the Institute of France; fellow of the Royal Astronomical Society of London; member of the Royal Institution, of the National Academy of Sciences, and of many others.

He has received the degree of D. C. L. from Oxford, D. Sc. from Cambridge, and, among numerous others, the degrees of LL.D. from the universities of Harvard, Yale, Princeton, Michigan, and Wisconsin. He has been awarded the Henry Draper Medal by the National Academy of Sciences, the Rumford Medal by the Royal Society of London, and the Rumford Medal by the American Academy of Arts and Sciences, as well as the Janssen Medal from the Institute of France, and the medal of the Astronomical Society of France.



Current Topics

THE point to which attention was most directly drawn by the fatal Paris underground railway fire a few months ago was that if all trains on such railways were made wholly of metal, and lined and furnished with incombustible materials, there could be no disaster of similar character, simply because there would be nothing to burn. It is interesting to note, in connection with this, to what extent the cars for the New York underground railway will be fireproof. According to recently published particulars of them, the bodies of the cars will be sheathed with copper. The floors will be of two thicknesses of hard maple, with asbestos fire felt between them. The floor sheathing will be of ¼-inch asbestos board, which will cover the whole under surface of the car body, and the under surface of the car directly over the motors will be sheathed with sheet steel one-quarter of an inch thick. The motor and the control cables will be incased in woven asbestos insulation, and asbestos moulded forms will be used to cover certain parts of the machinery. All incandescent and heater wires will be incased in flexible metallic conduits, each lamp will be attached to a ventilated cast-iron outlet box, and all heaters are incased in asbestos-lined metal boxes. Metal sheathing will be used in the platforms, and all the switches and fuses are mounted on a marble switchboard, which is placed in a steel compartment outside of the car. Sixteen incandescent lamps will be placed in the ceiling of each car, and twenty-four electric heaters will be used, in addition to one in the motorman's compartment. The car bodies will measure slightly over 42 by 8 feet, and each car will have a seating capacity for 52 persons.

WHILE the steam turbine has been making rapid progress on land for central power station work, its career as a marine engine has been relatively slow. Recently, however, there have been promising indications of substantial developments to come in that career, and these are likely to be furthered in great measure by the recommendation for the experimental installation of turbine engines in a 5000-ton cruiser, or scout ship, made by Admiral Melville on the day of his recent retirement from the post of Chief of the Bureau of Steam Engineering of the United States Navy. This recommendation has resulted in a decision by the Navy Department to

appoint a special board to examine carefully all available data with regard to the work of these engines, to inspect a number of vessels in which they have been installed, and to prepare an estimate to be submitted to Congress for an appropriation for a vessel of at least 5000 tons to be equipped with turbines. The board will determine whether the funds now at the disposal of the Department will defray the cost of installing turbines in a torpedo-boat or other smaller vessel, and, if this question is decided in the affirmative, practical tests may be made without waiting for action by Congress. In any event, the Department proposes to take immediate steps to settle the question of the availability of this type of engine for use in the United States Navy, and it is probable that at a comparatively early date one or more vessels will be equipped with turbines as the basis of elaborate and exhaustive tests.

Admiral Melville has summed up the advantages of the steam turbine substantially in the following manner:—With a turbine little or no care or precaution is required in starting or reversing, and these operations can be performed as rapidly as the necessary valves can be manipulated. Turbines are now reversed by means of a supplemental set of reversing blades and nozzles to which steam is admitted when desired. As the propellers used with turbines are smaller than those with reciprocating engines, the tips of the upper blades will be more deeply immersed and less likely to be uncovered by the pitching of the vessel, so there will be less possibility of racing. But even if racing does occur, there will be no risk of serious injury or breakdown, as with a reciprocating engine. There will be little or no vibration caused by the turbine, and the vibration from the propellers will be greatly decreased by reason of their smaller size. The absence of vibration and perfect balance of the parts will allow the use of much lighter engine platforms. The absence of all interior rubbing parts will allow highly superheated steam to be used, which cannot be done satisfactorily with the reciprocating engine; this, in turn, will add greatly to the economy of the turbine. As most water-tube boilers are well adapted to the use of superheaters, it is very probable that the introduction of turbines will quickly be followed by the use of superheaters for marine work.

As each turbine has but two bearings, Admiral Melville further points out, there is nothing to get out of line in the turbine itself. In the case of a reciprocating engine there are generally four main bearings that must be kept in perfect alignment and reciprocating parts that must be kept in right-angled alignment with the main bearings. As the turbine would have but two bearings, any working of the vessel would not disturb it and could tend to throw it out of adjustment only with the line shaft; this tendency, however, would be no greater than is now the case with the reciprocating engine. The absence of all working parts, except a few of the very simplest description, and especially the absence of leakages and interior rubbing parts in the steam spaces, reduces the cost and labour of upkeep to the minimum. This, though important, is not so important in the case of a naval vessel as is the ability to keep the sea almost indefinitely without laying off the engine for repair. The lubrication of a turbine is almost ideal, since the absence of adjustable bearings permits forced lubrication without appreciable loss of oil or any of it being carried into the condenser by the exhaust. The same oil can be pumped through the bearings over and over again, being cooled in passage by a water coil.

It is interesting here to recall that the first vessel propelled by a steam turbine, —the *Turbinia*,—was built in 1894. The original machinery consisted of a single compound turbine which drove

THE "REVOLUTION." THE FIRST AMERICAN-BUILT TURBINE YACHT. THE MACHINERY WAS BUILT BY THE CURTIS TURBINE CO., NEW YORK

one shaft carrying one 30-inch propeller. Multiple propellers were next tried, set about three diameters apart on the shaft. After this the original turbine was removed and replaced by three separate turbines,—high, intermediate, and low-pressure,—each driving a shaft with three 18-inch propellers, making nine propellers in all. These apparently gave the best results, though some recent experiments have shown single propellers on each shaft to be preferable. The *Turbinia* is 100 feet long, 9 feet beam, and has a displacement of 44½ tons. Speeds up to 32 knots were obtained with her.

THE tendency was next to apply the turbine to vessels where the conditions were most suitable to an essentially high-speed engine, and from the *Turbinia* the step to torpedo-boat destroyers was a short one. The matter was placed before the British Admiralty in July, 1897, and the order for the *Viper* was placed with the Parsons Marine Steam Turbine Company, Ltd., at Wallsend-on-Tyne, in January, 1898, for a 31-knot torpedo-boat destroyer, of the same dimensions as the usual 30-knot vessels of this class, viz., 210 feet in length, 21 feet beam, and about 370 tons displacement, but with machinery of much greater power than was usual in vessels of this size. Sir W. G. Armstrong, Whitworth & Co. also contracted with the company for machinery for one of their torpedo-boat destroyers, afterwards called the *Cobra*. The turbine engines of these vessels were similar to those of the *Turbinia*, but they consisted of two distinct sets of engines on each side of the vessel. There were four screw shafts in all, entirely independent of one another, the two on each side being driven by one high and one low-pressure turbine, respectively, of about equal power. The two low-pressure turbines drove the two inner shafts, and to each a small reversing turbine was also permanently coupled and revolved idly with them when going ahead. The screw shafts were carried by brackets, as usual, and two propellers were placed on each shaft, the foremost in each case having a slightly lesser pitch than the after one. In the *Cobra*, three propellers on each shaft were subsequently adopted. The thrust from the screw shafts was entirely balanced by the steam acting on the turbines, so that there was extremely little friction. The *Viper*, with a displacement of 370 tons, attained a mean speed of 36.58 knots, or nearly 42 miles, representing a development, for that tonnage, of about 11,500 H. P. Unfortunately, both these vessels were lost at sea before their efficiency under service conditions could be fully demonstrated; but the disasters could not in either case be attributed in the remotest degree to the fact that the vessels were propelled by turbines.

Of the several more recent turbine-propelled vessels,—passenger and pleasure boats,—an account was recently given by the Hon. C. A. Parsons in a paper before the Institution of Naval Architects, and from this the following particulars have been taken. Elsewhere in this issue illustrations also are given of some of these vessels, in the article entitled "The Steamship of the Future," and to these it may be of interest to refer. The first passenger vessel to be propelled by steam turbines, the *King Edward*, was built in the spring of 1901 by Messrs. W. Denny & Brothers, of Dumbarton, and engined by the Parsons Marine Steam Turbine Company, Ltd., to the order of Captain John Williamson, of Glasgow. She is 250 feet in length and 30 feet beam, and about 6 feet draught of water. The turbines are similar in construction to those of the *Turbinia*, and consist of three turbines, one high-pressure driving the centre shaft, and two low-pressures, working in parallel, driving the side shafts; in the exhaust casing of each of the low-pressure turbines is placed the reversing turbine. On the centre shaft is one propeller 57 inches in diameter, and on each of the side shafts are two propellers of 40 inches diameter and about 9 feet apart. On the trial of the *King Edward* a mean speed of 20.48 knots was recorded, the revolutions of the centre shaft being 505 and the side shafts 755. The indicated horse-power was estimated to be 3500 from model experiments in the tank at Dumbarton.

In 1902 the second turbine passenger vessel, the *Queen Alexandra*, was built by Messrs. W. Denny & Brothers for Captain John Williamson, and engined by the Parsons Marine Steam Turbine Company, Ltd. Her dimensions are 270 feet length, 32 feet beam, and about 6 feet 6 inches draught. Her machinery is similar to, but more powerful than that of the *King Edward*. On trial a mean speed of 21.43 knots was attained, the revolutions of the centre shaft being 750, and of the side shafts 1090. The indicated horse-power, taken from Messrs. Denny's tank experiments, was estimated to be 4400, and the consumption of steam was under 15 pounds per indicated horse-power. In the spring of this year the tandem side propellers were replaced by single propellers of larger diameter and somewhat finer pitch, which have had a beneficial result in greater smoothness of motion, and a slight improvement in the speed and coal consumption. The success of these two Clyde vessels has led to the adoption of turbines for the latest addition to the Dover-Calais and the Newhaven-Dieppe service, and these fine vessels constitute a very important step in advance for marine steam turbine machinery. The Dover-Calais boat *Queen*, for the South-Eastern & Chatham Railway Company, is 310 feet in length, 40 feet beam, and 25 feet depth. The machinery is designed for 8000 I. H. P. on service. The Newhaven-Dieppe boat, for the London, Brighton & South Coast Railway, launched a few months ago, is 280 feet in length, 34 feet beam, and 22 feet depth.

Of the three British-built yachts which have lately been fitted with steam turbines, the largest is the *Lorena*, built by Messrs. Ramage & Ferguson, Ltd., of Leith, to the order of Mr. A. L. Barber, of New York, and to the designs of Messrs. Cox & King, of London. This vessel is 253 feet in length on water-line, 33.3 feet beam, and has about 13 feet draught of water. The turbines are similar to those of the *King Edward* and *Queen Alexandra*, but somewhat larger, and designed for a speed of vessel of 16 knots. The adoption of turbines instead of reciprocating engines, as originally contemplated, permitted of a considerable increase of the saloon accommodation, besides saving 70 tons in the weight of the machinery. The steam yacht *Emerald*, built by Messrs. Alex. Stephen & Sons, Ltd., of Glasgow, has been the first vessel propelled by turbines to cross the Atlantic. Her dimensions are,—length, 198 feet; beam,

28 feet 7 inches; and displacement, about 900 tons. Her turbine machinery is also similar to that of the two Clyde vessels. She is fitted with one propeller on each shaft, and attained a mean speed of 15 knots on trial. The smoothness of running of the machinery and propellers is a noticeable feature. In crossing the Atlantic at the end of April she experienced very severe weather and head winds, but the propellers never raced and the machinery worked admirably and without the slightest hitch. The turbine yacht *Tarantula*, built by Messrs. Yarrow & Co., Ltd., of London, is similar in dimensions to a British first-class torpedo-boat, but of heavier scantlings. Still another turbine yacht,—of special interest as the first American-built boat of that order,—is the *Revolution*, illustrated on page 96, 178 feet long and 17 feet beam, driven by a Curtis turbine, which latter type is now being built in very large sizes for electric power plants.

To complete the record of turbine boats, reference should be made to the *Velox*, a torpedo-boat destroyer, built by the Parsons Company, and recently purchased by the British Admiralty. A noteworthy feature in this vessel is that two reciprocating triple-expansion engines form part of the equipment, each of 150 I. H. P., connected by detachable claw couplings to the low-pressure turbine shafts. At cruising speeds up to 13 knots, the steam, after working these engines, is exhausted into the turbines, where its expansion is completed before passing into the condensers. The turbines of the *Velox* are like those of the *Viper*. The displacement is 440 tons, and the coal consumption at 27 knots worked out at 2½ pounds per indicated horse-power per hour. The turbine machinery for another torpedo-boat destroyer,—the *Eden*,—of 7000 H. P., is now being built, and also for the *Amethyst*, a third-class cruiser of 9800 H. P. This machinery is similar, in general design and arrangement, to the engines of the passenger vessels previously mentioned. But, in view of the great variation in horse-power required in modern war vessels, two additional cruising turbines are permanently coupled to the shafts of the main low-pressure turbines. When working at reduced power, the steam from the boilers will pass through the cruising turbines in series, and thence to the main turbines. By this means a high ratio of expansion of the steam at all the lower speeds is obtained. In addition to the development of the steam turbine in the British Navy and merchant marine, the Turbinia Company, the German Parsons Marine Company, of Berlin, have received two large orders for marine turbine installations, to be used for the Imperial Navy of Germany. One is of 5000 H. P. for a sea-going torpedo-boat and the other for 10,000 H. P. for a small cruiser, the *Merkur*. These will be the first ships of the German Navy in which reciprocating engines have been supplanted by steam turbines.

So far as our present knowledge goes, all anxiety as to the durability of iron and steel frame buildings, now so popular in the United States, may be dismissed. It is conceivable, says *The Iron Age*, in recently discussing the subject, that under some conditions the deterioration would be very rapid, and that electrolysis might hasten disintegration; but no evidence has yet been found to warrant uneasiness on this score, or to give plausibility to the prophecy that the present tendency in architecture will go on until some lofty "sky-scraper" collapses into its own cellar excavation in a heap of rubbish and a cloud of dust. This may happen, but it will not be in consequence of unsuspected corrosion of steel members. Satisfactory proof of this appears to have been afforded by the recent deliberate demolition of the first of the modern steel frame buildings put up in New York. This building, used for hotel purposes, was intended to last a generation at least; but the ground which it occupied was needed for a more important purpose, and after

three years of life it had to go. Three years are not a long enough period to afford a basis for generalisation as to the life of steel frames; but in the demolition of this building, not well built originally, some facts were learned which are of interest and value. It is doubtful that if twenty years had been added to its life it would have told any very different story. The frame was run up with Z-bar columns, and the outside walls were supported at each story. The basement floor and the sidewalk beams and girders were supported on cast iron columns resting directly on the rock. All the steel columns were stepped into cast iron bases, with the exception of those of one wall, which were supported on grillage beams resting upon the rock. Reference to the specifications showed that the steel work was to be thoroughly cleaned of scale and rust before leaving the shop, and given a coat of boiled linseed oil, worked into all seams and open spaces; all pins, pin holes and machined surfaces were to be coated with tallow and white lead, and all contact surfaces were to be thoroughly painted before joining. Pieces which could not be reached for painting after joining were required to receive two coats of paint before erection. Grillage beams were coated with asphalt before setting in place. It is doubtful if these specifications were in every instance strictly followed; indeed, it may be said with confidence that they were not. The work was "rushed" under somewhat unfavourable conditions. The frame was joined in winter, work was more or less delayed by severe weather and heavy snow, and for part of the time the bricklayers and stone masons pushed the steel workers so hard that nobody paid much attention to the letter of the specifications. Construction was begun in November, 1898, and was finished in one year. The steel frame was taken apart in December, 1902.

It would not have been reasonable to expect to find in the steel members of the framing any evidences of very serious deterioration during this brief interval; but it was not at all unreasonable to expect that in three years deterioration would have begun, and that its direction and rate of progress could at least be approximated from the visible beginnings. As a matter of fact, it was the conclusion of the experts of the Bureau of Buildings that no other corrosion of consequence could be discovered than had obviously begun and gained measurable headway before the building was covered in. There was considerable rust behind the splice plates of the column connections on the fifth story. At about this point the work was arrested by snow and sleet, and in the eagerness of the contractor to make up for lost time it is probable that many requirements of the specifications, as well as certain specific provisions of the building code, were either disregarded or perfunctorily complied with. To this was undoubtedly attributable such deterioration as was noticed in the steel frame of the building. Absolutely nothing was discovered by the inspectors detailed to watch every step of the work of demolition which warranted the belief that in any period which could be forecast from data at hand the steel frame of this badly constructed building would not have lasted as long as the stone and brick work, and longer than in that position any building erected in 1898 would be likely to be profitably useful. This is only one of a number of examples showing that neither fire, wind strain nor rust is effecting the deterioration of steel frames as rapidly as those who first adopted this form of construction had reason to expect.

In dealing with the parts played by different nations in inventing, *The Engineer*, of London, recently pointed out, as the first and most obvious fact in this respect, that English-speaking nations are far ahead of all other nations. The things done by France, Germany, Austria, Russia, Italy, and Spain are as nothing compared with the work done by the men of Great Britain and the

United States. A search for the reasons why some nations invent and others do not, would constitute a most attractive, even fascinating, inquiry. The German, it may be said, is far more receptive than originative. He lacks that peculiar type of imagination about which Tyndall has written with so much charm, and the absence of which is fatal to the spirit of mechanical exploration on which the art of invention depends. It used to be said that Americans could invent nothing but little things like apple parers and clocks. The statement is no longer quite true; yet the suggestive and interesting fact remains that the people of the United States are still far ahead, even of France or Switzerland, in the art of inventing small mechanism, such, for example, as the sewing machine, and machines used for making boots and shoes. Germany, with a superb system of scientific education, apparently can originally invent nothing outside chemicals but a class of cheap commodities with which to undersell other nations. While it is not maintained that the scientific training is responsible for this, the evidence, which may be taken for what it is worth, is that Charlottenberg does not turn out men with epoch-making inventions seething in their brains. So far as can be seen, indeed, it seems to be probable that in the future, as in the past, the progress of mankind will be due to genius far more than to education in any conceivable shape or form. To the end the engineer will be, like the poet, born, not made; and this particular type of genius seems to be peculiar to English-speaking races. It is not in any way clear, moreover, that the education of the college or the technical school is in any way helpful to the man of original thought. As a matter of course he must be educated; but men of this type generally settle for themselves what their education shall be, and they will not care for orthodox methods of getting it.

LIQUID hydrogen is by far the coldest liquid known at the present time. At ordinary atmospheric pressure it boils at —422 degrees F., and reduction of the pressure by an air pump brings the temperature down to —432 degrees, at which the liquid becomes a solid, resembling frozen foam. According to Professor Dewar, to whom the credit is due of having liquefied hydrogen in 1898, the liquid is a colourless, transparent body, and is the lightest liquid known to exist, its density being only one-fourteenth that of water; the lightest liquid previously known was liquid marsh gas, which is six times heavier. The only solid which has so small density as to float upon its surface is a piece of pith wood.

PHOTO BY AIME DUPONT, NEW YORK

Alex C. Humphreys

PRESIDENT OF STEVENS INSTITUTE OF TECHNOLOGY

SEE PAGE 193

UNDEXED

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SMITHSONIAN

RECENT DEVELOPMENTS IN NIAGARA POWER

By H. W. Buck, Electrical Engineer of the Niagara Falls Power Co.

THIS WILL BE THE APPEARANCE, WHEN COMPLETED, OF THE POWER HOUSE OF THE CANADIAN NIAGARA POWER COMPANY. CAPACITY, 110,000 H. P.

WHEN the first power house at Niagara Falls was proposed for a capacity of 50,000 H. P., with an ultimate tunnel capacity of 100,000 H. P., many people wondered how it would be possible to dispose commercially of such a large amount of electric power. Central station managers who, after a strenuous canvass for new customers, had been accustomed to increasing the output of their plants by the addition of a 150 KW Edison bipolar machine, were staggered by the magnitude of the quantities involved in this new proposition. Skeptical opinions were expressed based upon industrial and electrical conditions then existing, and these opinions at that time were, in the main, correct.

Since that time, however, great developments have taken place in the electrical arts which have made possible the present realisation of such a demand for power. The developments which have created this demand have been, first of all, in electro-chemistry, though the output of the Niagara plant is not confined to electro-chemical

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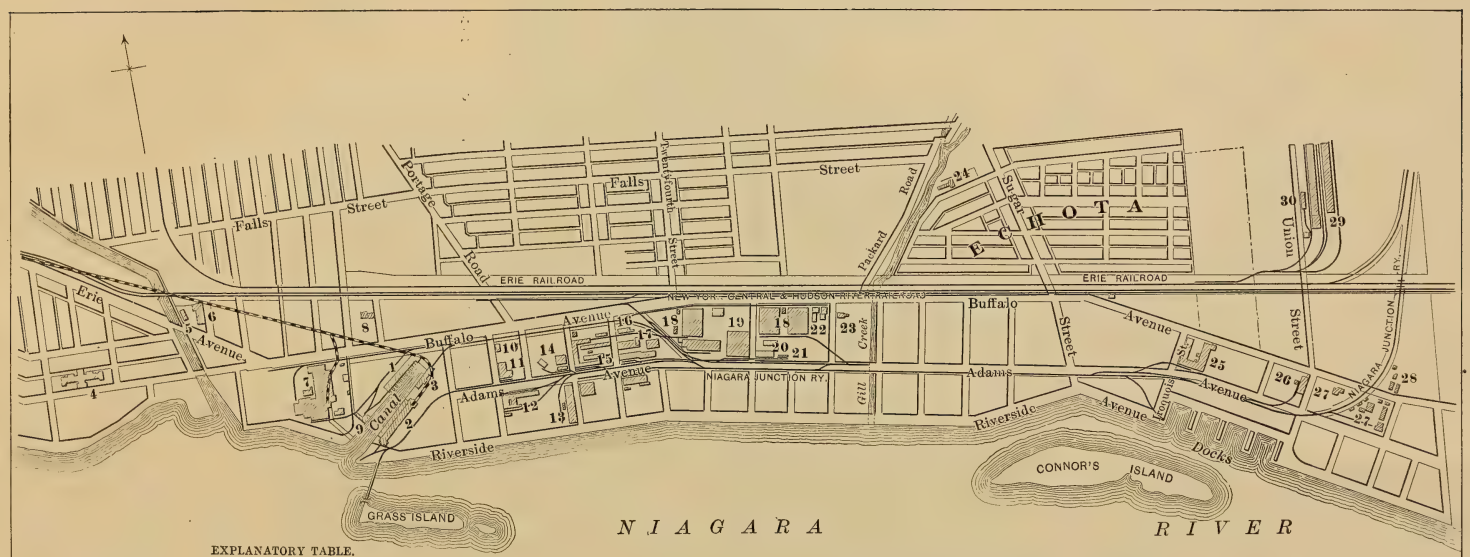


EXPLANATORY TABLE.

1. Power House No. 1.
2. Power House No. 2.
3. Main Transformer Station.
4. The Natural Food Co.
5. Francis Hook & Eye & Fastener Co.
6. Niagara Surface Coating Co.
7. International Paper Co.
8. Buffalo & Niagara Falls Electric Light & Power Co.
9. The Niagara Falls Water Works Co.
10. Niagara Research Laboratories
11. Electrical Lead Reduction Co.
12. By-Products Paper Co.
13. Composite Board Co.
14. International Acheson Graphite Co.
15. The Carborundum Co.
16. Atmospheric Products Co.
17. The Pittsburg Reduction Co.
18. Castner Electrolytic Alkali Co.
19. Niagara Electro Chemical Co.
20. The United Barium Co.
21. Ampere Electro Chemical Co.
22. Norton Emery Wheel Co.
23. Acetyvone Manufacturing Co.
24. Echota Disposal Works
25. Ramapo Iron Works
26. Roberts Chemical Co.
27. Oldbury Electro-Chemical Co.
28. Phosphorus Compounds Co.
29. Union Carbide Co.
30. Union Street Sub-station

The Niagara Falls Power Company

GENERAL MAP

SHOWING

LOCAL DISTRIBUTION

OF

ELECTRIC POWER

Scale of Feet

500 200 0 500 1000 1500 2500

applications, as is generally supposed. Large blocks of its power are in use for electric railway propulsion, electric lighting, and mechanical power application. One of the most recent and important factors in the growth of this power system has been the introduction of the electric motor drive for factory appliances. The evolution of economical methods in power transmission has made the delivery of Niagara power commercially possible to a widely scattered market.

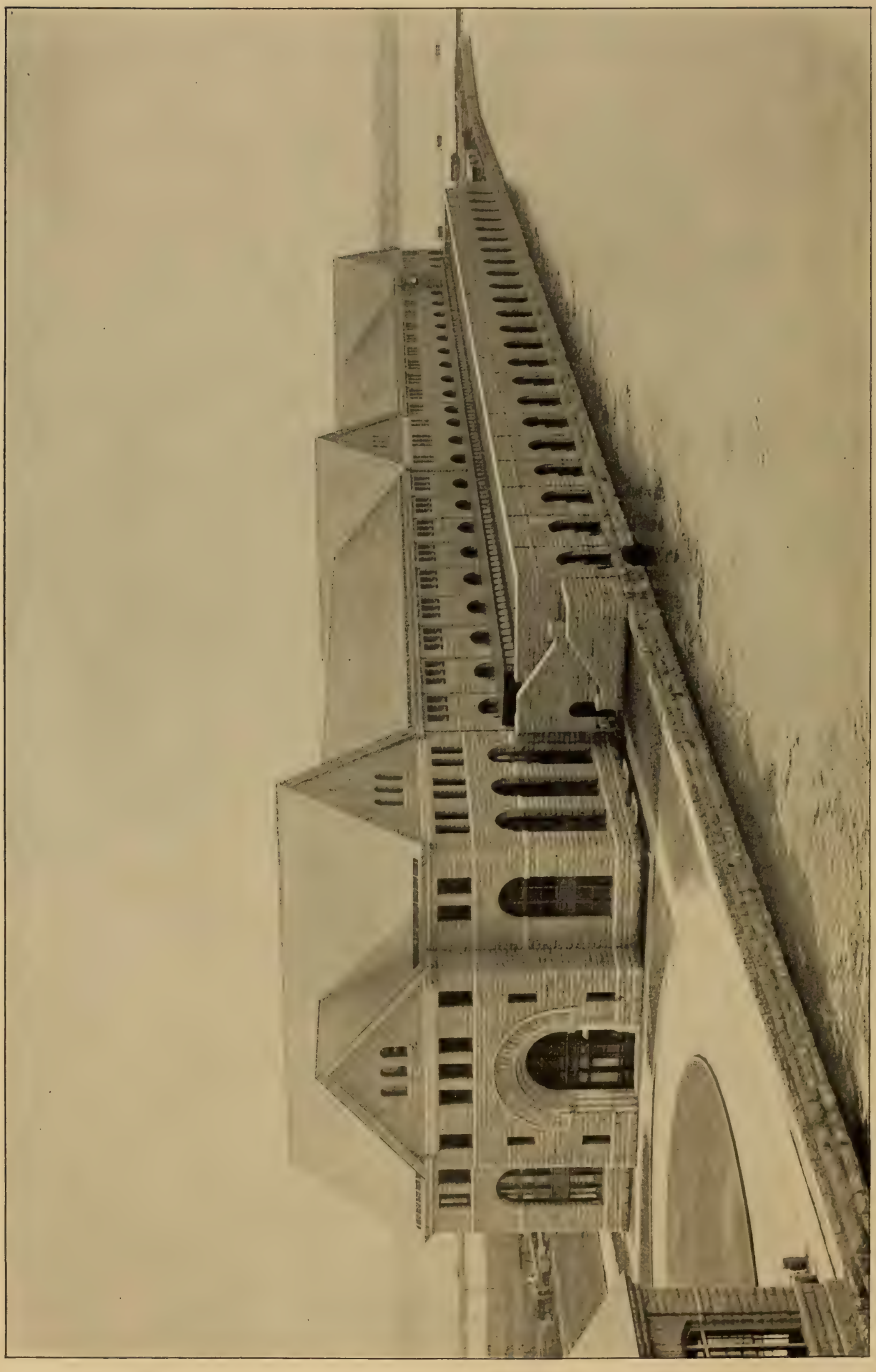
As a result of these developments in the application of electrical energy the first power house has reached the limit of its capacity of 50,000 H. P.; the second plant, having a capacity of 55,000 H. P., is well along towards its limit, and a third power house of 110,000 H. P. is being constructed on the Canadian side of the river to operate in conjunction with the first two, thus making a total of 215,000 H. P.

The second plant on the American side, known as Power House No. 2, is constructed near the first power house, but on the opposite side of the inlet canal, and its turbines discharge their water into the original tunnel through a short branch connection. Its equipment consists of eleven 5000 H. P., vertical shaft, 2200-volt, 25-cycle, two-phase generators of the same speed as those in the first plant, viz., 250 revolutions per minute. The first six machines of the installation are of the external revolving field or umbrella type; the last five generators have internal revolving fields with outside stationary armatures, the speed remaining the same. The general appearance of this latter generator is well shown in the illustration on page 107, and a marked contrast will be noted between it and those of the external field design. This internal revolving field construction affords many advantages of simplicity and accessibility to the various parts of the machine.

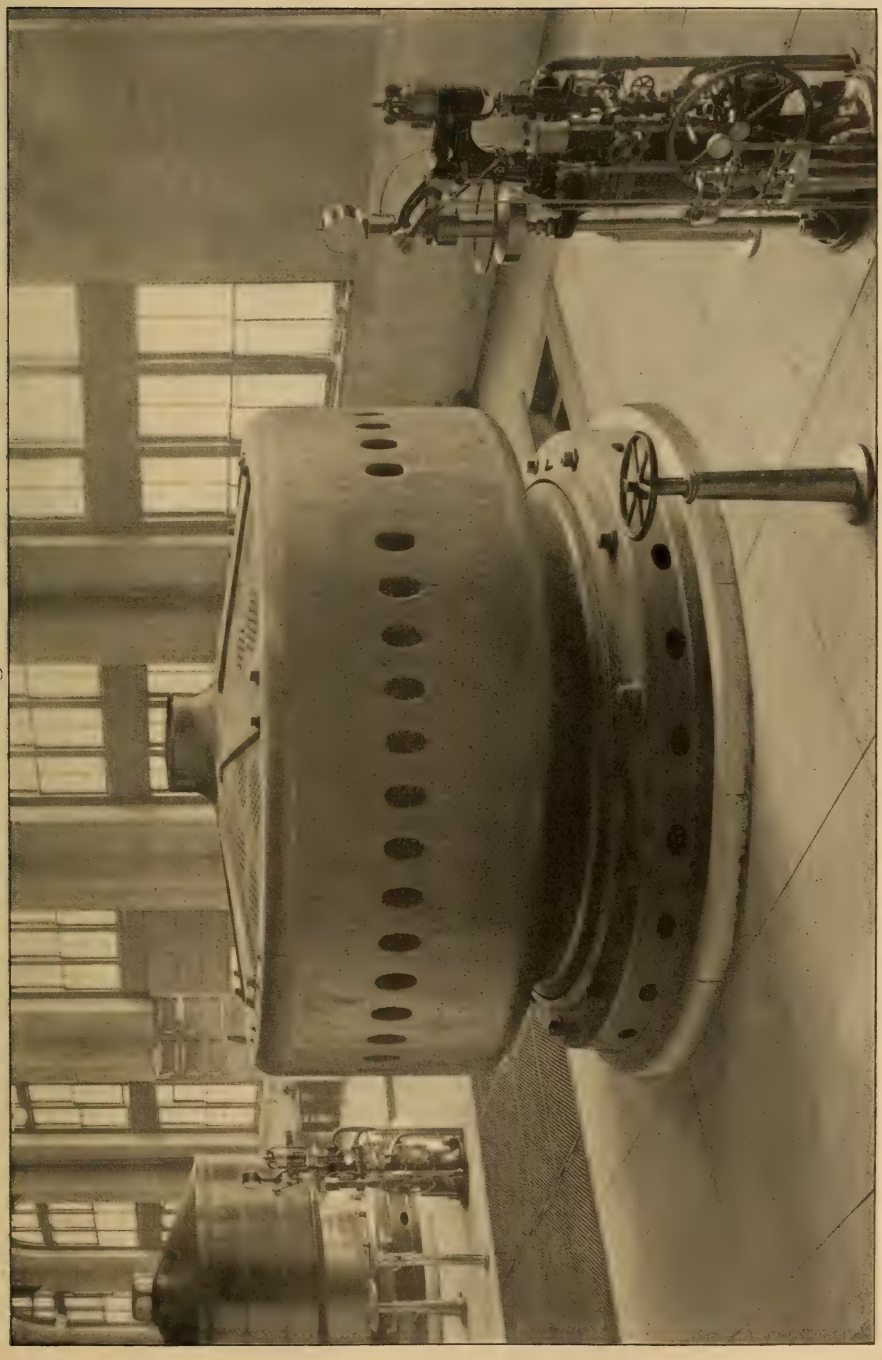
The general construction of Power House No. 2 is the same as that of the older plant, with which almost everyone is familiar. The changes introduced have been principally along the line of improvements in detail which have been the result of the evolution which has taken place in engineering methods since the first plant was installed. The turbines were built by the I. P. Morris Company, of Philadelphia, from designs of Escher, Wyss & Co., of Zürich, and the electrical equipment was manufactured by the General Electric Company, of New York. The output of this plant is used for local service to customers on the lands of the Niagara Falls Power Company, the Union Carbide Company alone taking a block of 15,000 H. P. Seven generating units are now in operation, and by January 1, 1904, the plant will be entirely completed with eleven 5000 H. P. units.

As stated above, a third power house is being constructed on the Canadian side of the river, which will serve to supply the demand for power in both Canada and the United States when all the power from the two American plants is taken up. The work is being carried on by the Canadian Niagara Power Company, a Canadian corporation controlled by the Niagara Falls Power Company. The capacity of this plant, when completed, will be 110,000 H. P. In general, its hydraulic development will be similar to that of the American plants. The power house is situated in the Queen Victoria Niagara Falls Park, about half a mile above the Horseshoe Falls. The water is taken in from the river through a short canal and forebay, discharged through penstocks into turbines near the bottom of a wheelpit, and carried away to the lower river through a tunnel about 1700 feet in length.

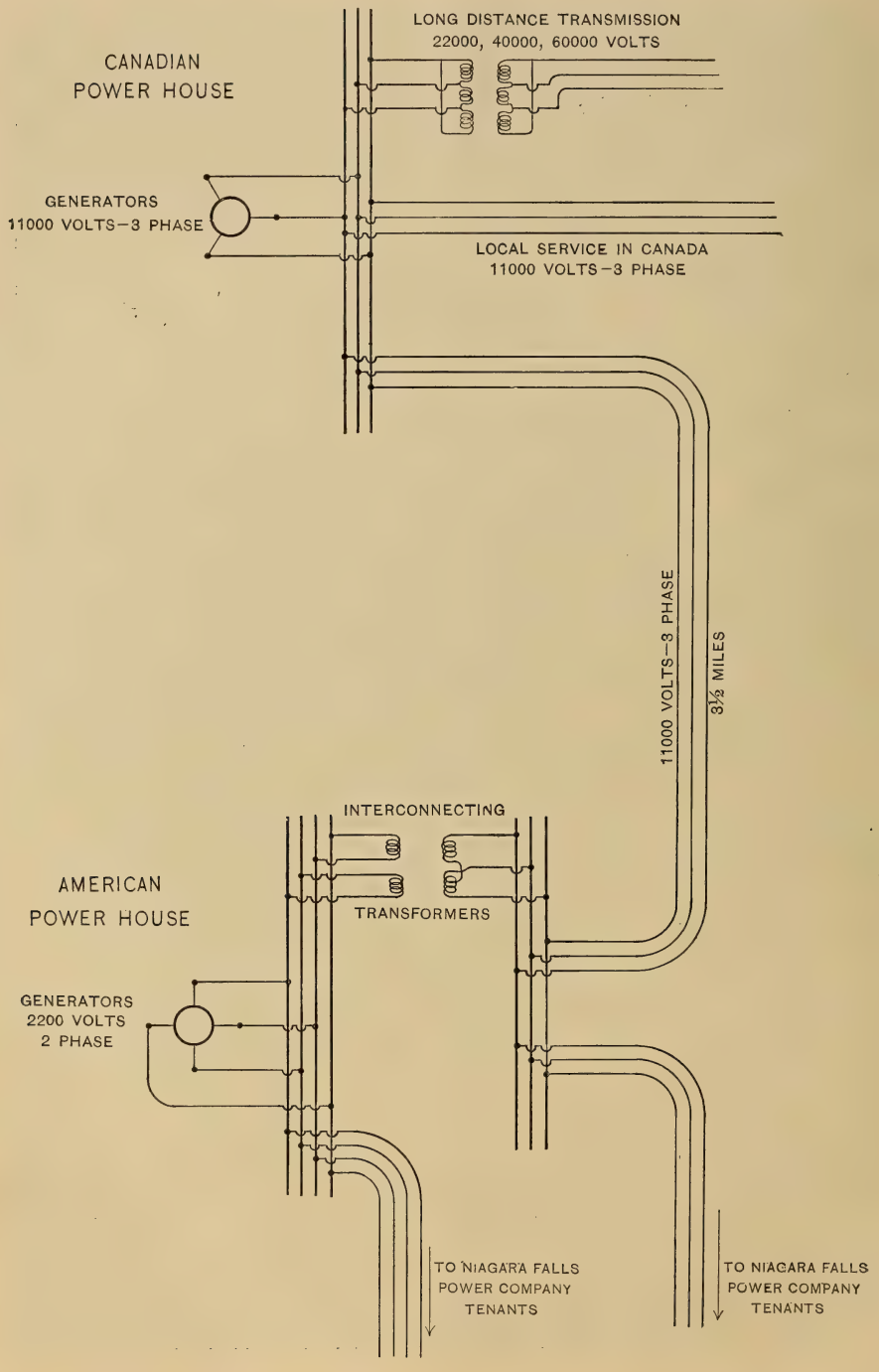
The most distinctive feature of this plant is the size of the generating units, each of which is to have a capacity of 10,000 H. P.,—the largest machines which have thus far been constructed. The plant, when completed, will comprise eleven of these generators. A unit of this size was adopted for reasons of economy in hydraulic development and in electrical equipment. These 10,000 H. P. units occupy but little more space than those of 5000 H. P. Thus results a great reduction in length of wheelpit and power house for a given



POWER HOUSE NO. 2 OF THE NIAGARA FALLS POWER COMPANY



ONE OF THE INTERNAL REVOLVING FIELD GENERATORS FOR POWER HOUSE NO. 2



METHOD OF INTER-CONNECTING THE AMERICAN AND CANADIAN POWER SYSTEMS

horse-power output. Furthermore, the generators cost considerably less per horse-power than those of 5000 H. P. capacity.

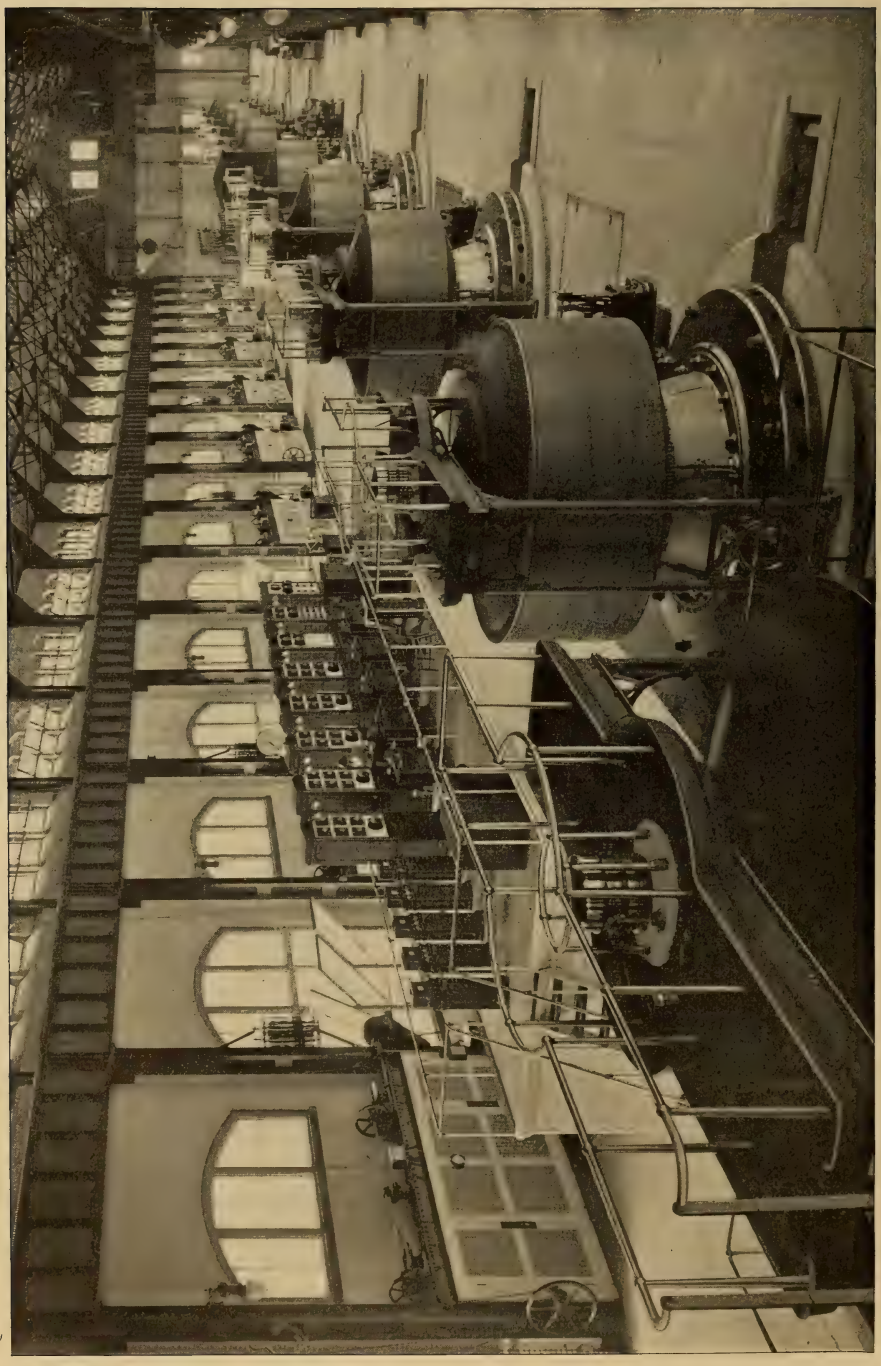
The generators will have vertical shafts, and their general design is well shown n the illustration on page 112. They are wound for three-phase current, 11,000 volts, 25 cycles at 250 revolutions per minute. This high generated voltage was selected not for long-distance transmission, but for economy in local distribution of power. The cost of distributing underground at 11,000 volts, three-phase, is about one-fifth that required for a 2200-volt, two-phase system. For long-distance transmission step-up transformers will be used to raise the voltage to 22,000, 40,000, or 60,000 volts, depending upon the distance of transmission. Three-phase was decided upon rather than two-phase for the reason that one less conductor is required, which simplifies cable connections, and because the three-phase system requires 25 per cent. less copper for transmission than one of two-phase for the same voltage. Power from this plant will be distributed by means of No. 000 B. & S. triple conductor, lead-covered cables laid in ducts underground.

The first installation in the Canadian plant will consist of five such 10,000 H. P. generators, which are being built by the General Electric Company. The turbines, of like capacity, have been designed by Escher, Wyss & Co., and are under construction at that company's factory at Zürich. It is the intention to have cable connections so that this Canadian power house can operate, if desired, in parallel with either or both of the American plants. The method of accomplishing this is shown in the diagram opposite, the cables being carried across Niagara river by way of the upper steel arch bridge, a total distance of about three and one-half miles. The 11,000 volts, three-phase, will be changed to 2200 volts, two-phase, for paralleling, by means of step-down transformers, as shown in the illustration, or delivered direct to tenants on the lands of the Niagara Falls Power Company. This plant will be in operation by July 1, 1904. Its output will be used for Canadian industries in the province of Ontario within transmission distance of the power house, or for American consumers, as the demand may be. A part of its output may be sent to Buffalo by a transmission line to be built on the Canadian side of the Niagara river.

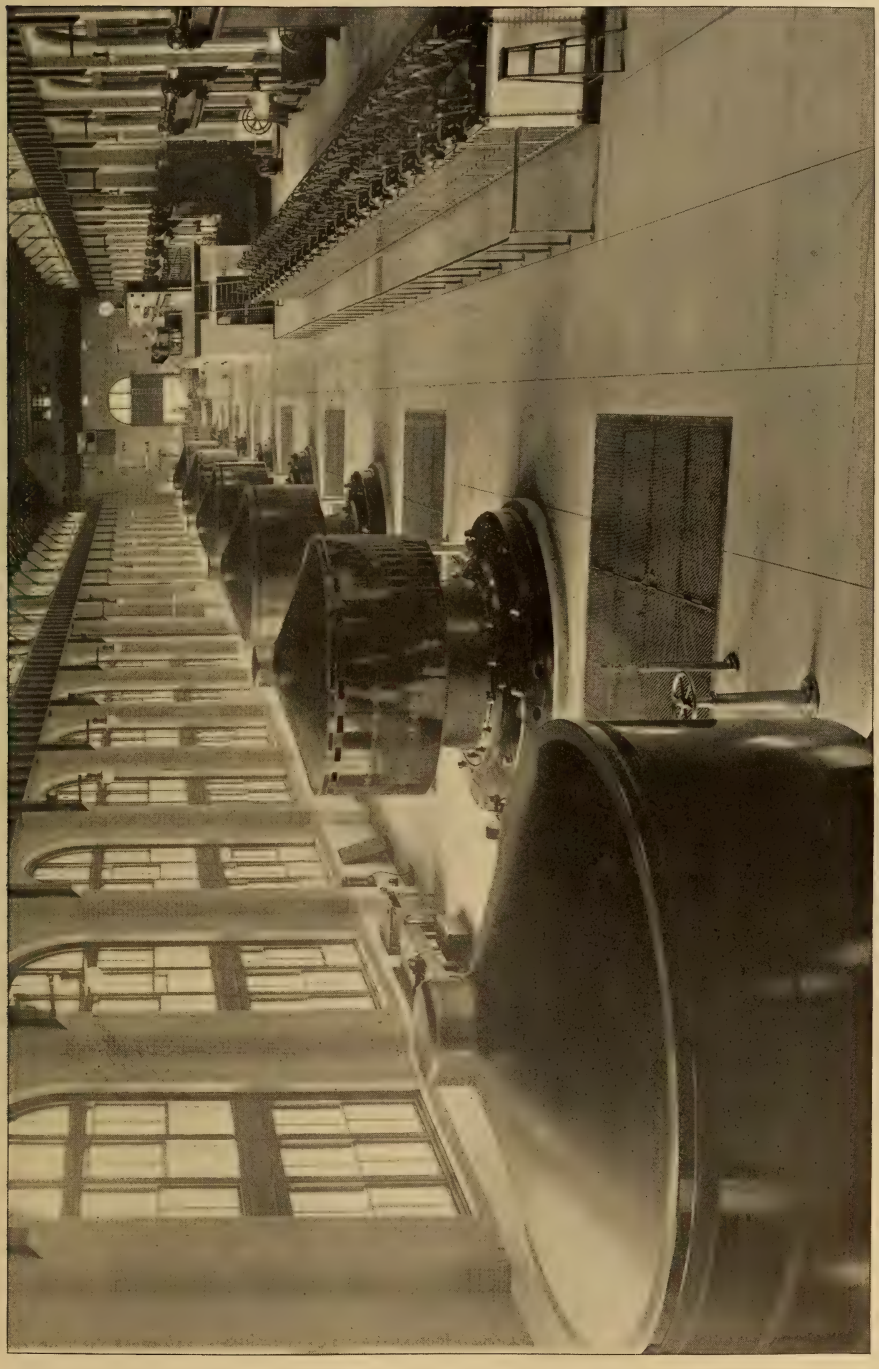
The Niagara power system now covers a very large territory; thousands of people are dependent upon it in their daily lives, and commercial interests of great importance are involved in it. The industrial world has learned that the Niagara power enterprise is no longer an experiment, and that it has already become an important factor in the manufacturing status of this continent. Its extent and the great variety of the industries which it operates will be seen from the list which follows:—

NIAGARA POWER SYSTEM. LIST OF CUSTOMERS

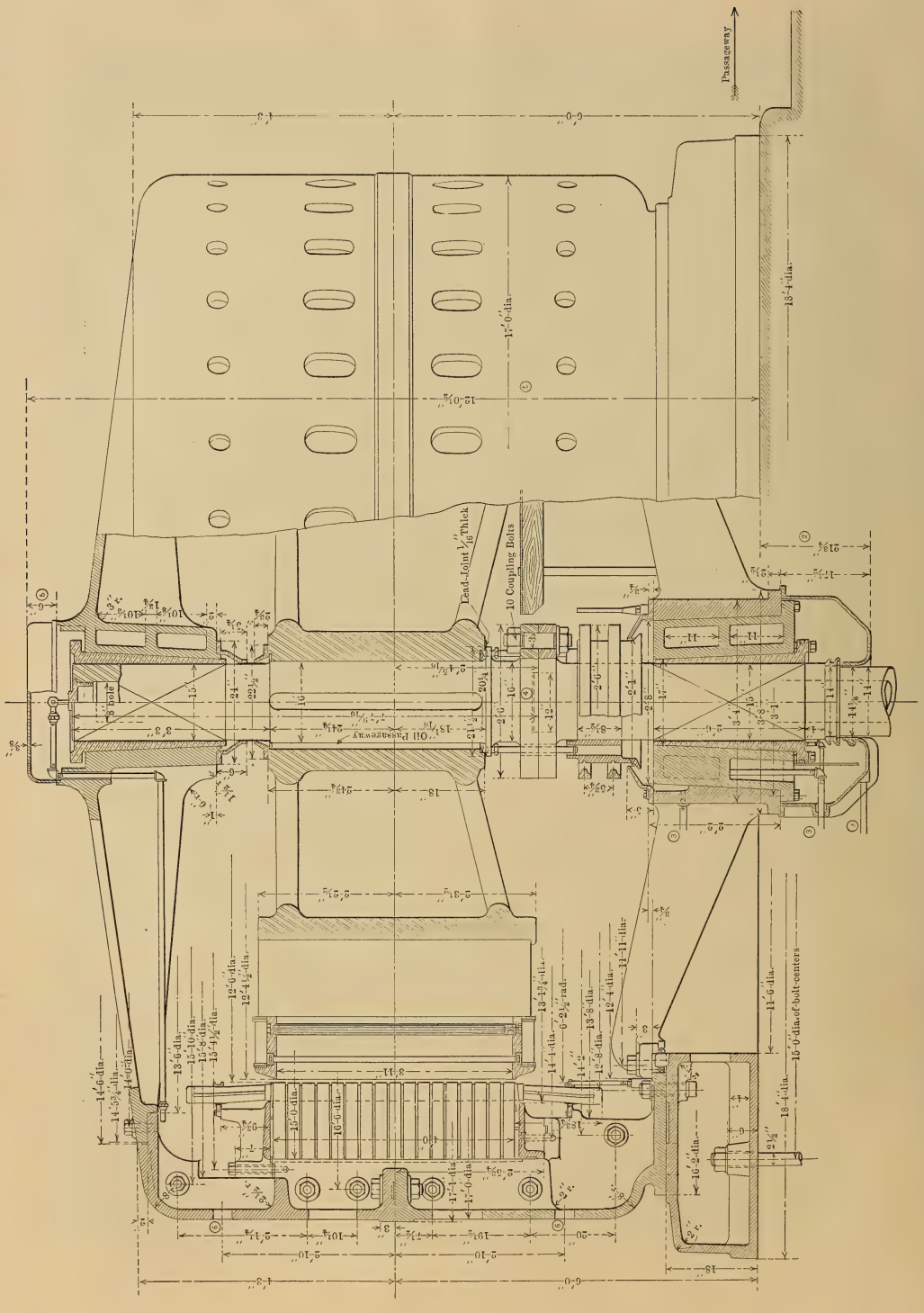
NIAGARA FALLS, N. Y. Name	Maximum Power Used H.P.	Distance From Power House Miles
The Pittsburg Reduction Co	8,000	0.46
The Carborundum Company	5,000	0.38
Union Carbide Company	15,000	2
Niagara Electro-Chemical Company	2,000	0.75
Niagara Falls Lighting Company	1.000	0.14
International Railway Company	1,500	--
The Niagara Falls Water Works Company, hydraulic power	300	--
International Paper Company, hydraulic power	8,000	--
Castner Electrolytic Alkali Company	7,000	0.85
Niagara Development Company	100	1.23
Oldbury Electro-Chemical Company	1,500	2.18
Electrical Lead Reduction Company	500	0.19
International Acheson Graphite Co	1,000	0.28
The United Barium Company	2,000	0.66
Acetyvone Manufacturing Company	50	0.95
Roberts Chemical Company	500	1.90
Francis Hook & Eye & Fastener Co	15	0.47
Norton Emery Wheel Company	650	0.95
The Natural Food Company	1,500	0.66
Ramapo Iron Works	500	1.70
By-Products Paper Company	500	0.19
Composite Board Company	200	0.34
Atmospheric Products Company	50	0.47
Niagara Research Laboratories	500	0.28
NIAGARA FALLS, ONTARIO		
A. C. Douglass, contractor	400	3
M. P. Davis, contractor	300	3.7
A. C. Jenckes, contractor	200	3.5
The Carborundum Company	200	3.6
Niagara, St. Catharines & Toronto Ry. Lighting Company	500	3.8
	300	3.4
TONAWANDA		
International Railway Company	1,500	--
Tonawanda Board & Paper Company	1,200	15
Buffalo Bolt Company	160	14
Philip Houck Milling Company	142	14
F. J. Alliger Company	107	15
Adamite Abrasive Company	50	14.5
Orient Manufacturing Company	20	14
Felton School	22	14



A RECENT VIEW OF THE INTERIOR OF POWER HOUSE NO. 1 OF THE NIAGARA FALLS POWER COMPANY. CAPACITY, 50,000 H. P.



INTERIOR OF POWER HOUSE NO. 2. CAPACITY, 55,000 H. P.



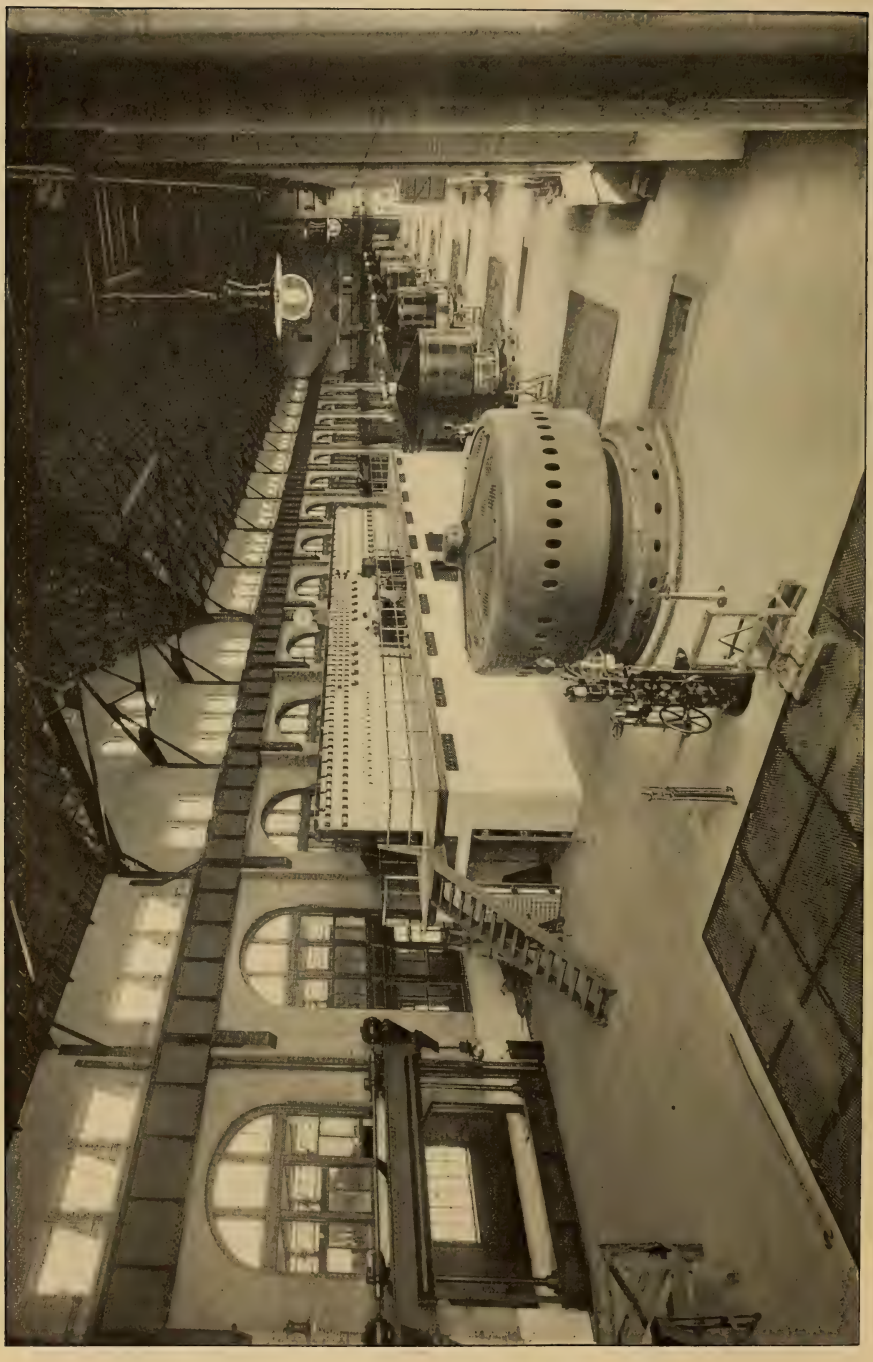
SECTION AND ELEVATION OF ONE OF THE 10,000 H. P. GENERATORS FOR THE CANADIAN NIAGARA POWER COMPANY

LOCKPORT	Maximum Power Used	Distance From Power House
Name	H.P.	Miles
Lockport Lighting Company	500	25
International Railway Company	1,000	26
OLCOTT		
International Railway Company	1,000	39
BUFFALO		
Buffalo Railway Company	7,000	27
Buffalo General Electric Company	6,000	27.6
The Charles G. Curtiss Company	125	25.5
McKinnon Dash Company	100	24.4
Pratt & Letchworth	233	24.5
W. W. Oliver Manufacturing Company	15	24.7
Acme Steel & Malleable Iron Works	50	24.8
N. Y. Car Wheel Works	200	24.3
National Battery Company	90	26.3
Standard Plaster Company	100	25.5
Great Northern Elevator Company	900	29.5
Buffalo Dry Dock Company	133	30
Electric Grain Elevator	200	30.7
Barcalo & Boll Manufacturing Co	60	30
Schoellkopf & Co	50	30
Iron Elevator & Transfer Company	165	30
Great Eastern Elevator	900	30
Sidney Shepard & Co	100	30
J. I. Prentiss & Co	30	29
Edward Elsworth & Co	150	30
American Agricultural Chemical Co	125	32
Jacob Dold Packing Company	100	32.5
Empire Bridge Company	90	33
Buffalo Elevating Company	950	29
John Kam Malting Company	225	24.3
American Brake Shoe & Foundry Co	40	33.2
Buffalo Cereal Company	375	30.3
Taylor Signal Company	65	25.5
Snow Steam Pump Works	150	33.3
Wood & Brooks Company	100	24.4
U. S. Rubber Reclaiming Works	995	31.7
American Radiator Company	200	24
Cumpson-Prentiss Coffee Company	30	29.1
Duffy Brothers & Nellis	50	33.5
Buffalo Foundry Company	240	35.1
H. O. Mills	255	29.3
Jewett Manufacturing Company	30	24.8
Buffalo Pitts Company	187	35.5
Buffalo Brake Beam Company	30	25
Buffalo Dental Manufacturing Co	20	35.5
Keystone Manufacturing Company	25	24.8
R. L. Ginsburgh & Sons	33	34
Buffalo Weaving & Belting Company	65	25.5
H. W. Dopp & Co	10	25
Frontier Iron Works	15	25
The Crosby Company	50	33
Lackawanna Steel Company	70	29.4
West Manufacturing Company	40	28
Buffalo Gasoline Motor Works	20	25
Pratt & Lambert	10	24.5
Wegner Machine Company	40	29
Spencer Kellogg Company	500	29.2
Hygienic Food Company	300	32.3
Collins Baking Company	50	33.2
George Urban Milling Company	450	34.5
Niagara Mill & Elevator Company	100	26
D., L. & W. R. R. Shops	150	34.5
Ryder Belt & Cordage Company	65	24.7
United States Headlight Company	40	26
George E. Laverack Building	100	28.2
Buffalo Structural Steel Company	30	26
J. N. Adam & Co	100	28.2
Genesee Hotel	100	28.1

The figures given are for maximum power used in each case. Since the maximum in the various plants does not occur at the same time, the resultant maximum at the power house is somewhat less than their sum. At present it amounts to about 75,000 E. H. P.

In the industrial world to-day close competition in the market for manufactured products has greatly reduced margins of profit. All possible economies, therefore, in cost of production become necessary, and factory managers in whose processes power is an important element are investigating in a more scientific way what their power costs them per annum. Nowadays, when the work of the factory is carried on so largely by machines, and not by men, the power cost becomes one of the controlling features in a plant. For these reasons factory managers in many cases are turning their attention toward Niagara power for the economies resulting from its use.

In modern factory construction the steam engine as a prime mover, belted to a long line of counter-shafting extending throughout the shop as a means of factory drive, has become largely obsolete. If a steam engine is used, it is direct-connected to an electric generator, which transmits power electrically throughout the shop to individual motors at each appliance or group of appliances. This has been the important development in factory operation which has educated the manufacturing public into the use of electricity and has helped to create the present demand for Niagara power. The factory manager about to start a new mill, having in mind the use of Niagara power, does not have to decide between a steam engine belted to counter-shafting on one hand and a complete electric motor equipment on the other, necessary for the use of Niagara power. He has probably made up his mind to use electric drive in any case. His decision, therefore, rests between a boiler room, smokestack and steam engine direct-connected to an electric generator as a means for supplying current to his motors, and the use of Niagara power for the direct supply of current to his factory circuits by simply bringing in wires from the street. The gain in simplicity in the latter case, and the economy of space, are self-evident. As to the cost of Niagara power drive, it can be stated that power is supplied from the Niagara system for less than



THE SWITCHBOARD IN POWER HOUSE NO. 2

one-half what it costs from any of the steam-driven central stations in the country, or from any isolated steam plant. Electro-chemical industries using large blocks of power continuously for twenty-four hours each day save 75 per cent. in their annual cost of power by obtaining it from the Niagara system.

What the exact status of the Niagara power system will be ten years hence is difficult to state, but that it will be vastly increased seems a certainty. The economy in the use of water-power for manufacturing and other purposes and the fact that all the small water-powers throughout the country are rapidly being taken up to their limit will, of necessity, turn the power user toward the Niagara frontier. Furthermore, the constantly increasing cost of coal tends to discredit the use of steam power for manufacturing.

No power system in the world can compare in point of reliability with that of the Niagara Falls Power Company, where three large independent generating plants are available for the supply of a single group of customers. By means of the electrical inter-connections which exist between these three plants any one of them could be completely shut down, and the customers, to whom the continuous supply of power is essential, supplied with power without interruption. This is a matter of great importance, especially from the standpoint of the possibility of the large steam railways using Niagara power, where continuous train service is demanded.

Discovery and invention in the electro-chemical field is very active, and some processes are in sight which will require large blocks of power for their operation. All these tendencies in industrial conditions, which have been mentioned, result in an accelerating demand for power from Niagara Falls.

MULTI-CYLINDER LOCOMOTIVES

A REVIEW OF THE WORLD'S PRACTICE IN MULTI-CYLINDER SIMPLE AND COMPOUND LOCOMOTIVES

By J. F. Gairns

PART I.—MULTI-CYLINDER SIMPLE LOCOMOTIVES

A QUARTER of a century ago non-compound locomotives having more than two cylinders were comparatively scarce, and, with the exception of one or two types, might have been classed as experiments and freaks even in cases where they were certainly not failures. Compound locomotives with two or more than two cylinders had, for all practical purposes, not made their appearance, although a few attempts to apply the compound principle to locomotives had been made or suggested.

The past twenty-five years, however, have seen many changes in locomotive design, involving in some cases rather striking departures from orthodox practice. To-day there are many multi-cylinder non-compound types in more or less extended use, and undoubtedly successful, while the compound locomotive with two, three, four and even more cylinders is an acknowledged success, and engines of the various types are being rapidly introduced in ever-increasing numbers in all parts of the world.

No method of classification for multi-cylinder simple locomotives is altogether satisfactory, but the following may be said to be the principal reasons which have caused the adoption of more than two high-pressure cylinders:—

1.—To dispense with coupling-rods in a four-driver engine.

2.—To obtain a more regular turning effect than can be obtained with two cylinders driving cranks at right angles, and to balance the engine.

3.—To produce a more powerful engine.

4.—To increase the power without unduly loading any one axle, or to provide a sufficiently powerful locomotive for use where the weight per axle is limited or where other conditions restrict dimensions.

5.—To provide a "flexible" locomotive, for use on roughly-laid tracks, and on curved lines.

Many of the locomotives to be described cannot be strictly allocated to any one section, but as far as possible the above classification will be followed.

1.—ENGINES WITHOUT COUPLING-RODS

What is believed to be the first multi-cylinder locomotive ever built belongs to this section.

In 1827 Messrs. Wilson & Co., of Newcastle-on-Tyne, supplied an engine to the Stockton & Darlington Railway, with four cylinders, two for each pair of driving wheels. Probably the difficulty of procuring wheels of exactly equal diameters, and a distrust of coupling-rods in those "pre-steel" days, were responsible for such a new departure; but the engine was a failure. Very few details of this engine are available, and no drawing is extant, but Fig. 1 probably indicates its general arrangement. This engine was rebuilt by Timothy Hackworth and converted into a six-coupled, two-cylinder engine, in which form it did good work and achieved historical fame as the "Royal George."

It was not until 1862 that any other engines were built with uncoupled driving wheels; but in that year M. Petiet, locomotive superintendent of the Northern Railway of France, put in service

eight passenger tank engines of the design illustrated by Fig. 2. These engines had driving wheels at each end, two cylinders to each pair, and three intermediate carrying axles. They were designed for fast service, but proved to be "rough riders" in consequence of their long, rigid wheel base, and although some of them lasted until 1883, there is no record of noteworthy work done by them. In their later years they were principally employed on shunting and other yard work. The cylinders were about 14 inches in diameter with 13-inch stroke; the driving and the carrying wheels measured, respectively, 63 and 42 inches; and the service weight of the engine was 48 tons, of which 23 tons were available for adhesion. These engines were also novelties in other ways. For instance, the chimney was carried back along the top of the boiler through a steam chamber so as to act somewhat as a superheater. Several twelve-wheeled goods engines with two distinct sets of coupled wheels of the same general design were constructed, but these will receive attention later on in their proper place.

Many years elapsed before the "free-wheel" principle was again employed in locomotive design, and then, in 1882, it was in connection with compound locomotives on Mr. F. W. Webb's three-cylinder engines for the London & North Western Railway. In 1889 M. De Glehn, whose name is now well known in the locomotive world, also used uncoupled wheels in his first compound engine.

At the Chicago Exposition of 1893 was shown a private locomotive belonging to its designer, Mr. F. C. Winby, and built by Messrs. Hawthorn, Leslie & Co., Ltd., of Newcastle-on-Tyne. It had four high-pressure cylinders, two inside actuating the front driving axle, and two outside, set back on the frames, actuating the rear driving axle, the two pairs of driving wheels being uncoupled. This engine, the "James Tolman," though universally acknowledged to be a splendid specimen of British workmanship, was a failure, and nothing was

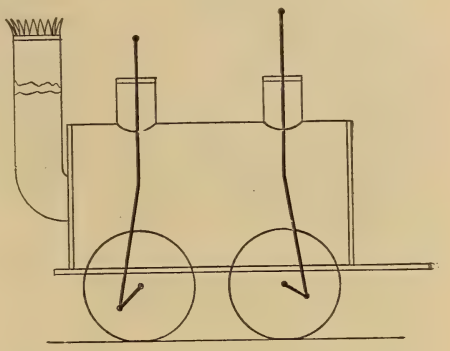


FIG. 1.—FOUR-CYLINDER ENGINE ON THE STOCKTON & DARLINGTON RAILWAY. NO COUPLING RODS

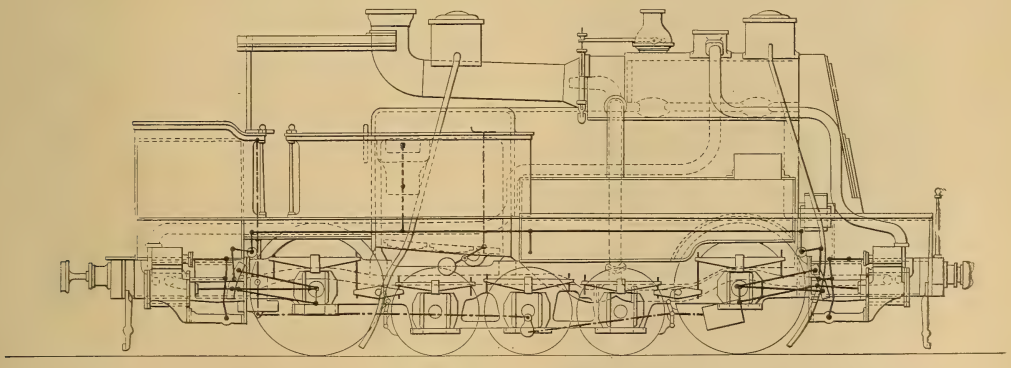


FIG. 2.—PETIET'S FOUR-CYLINDER SIMPLE-PASSENGER ENGINE ON THE NORTHERN RAILWAY OF FRANCE, 1862

FIG. 3.—THREE-CYLINDER LOCOMOTIVE BUILT BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA

done to utilise it, as would appear to have been quite feasible, by rebuilding on more ordinary lines. It is now in the locomotive museum of an American university.

The boiler presented many features of novelty, and it is probable that in this is to be found the cause of failure, as it is said that the engine easily ran out of steam. There was also other departures from ordinary practice with which we are not concerned.

In 1897 Mr. Dugald Drummond on the London & South-Western Railway adopted the same wheel and cylinder arrangement, but with more ordinary and reasonable dimensions, this time with success. These engines are still used for very heavy express service, and though there is only a limited scope for them to show their capabilities, they have equalled all expectations, and will probably be multiplied when occasion arises, unless Mr. Drummond becomes a convert to the compounding of locomotives in the interim. Fig. 17 illustrates one of these engines ready to go into the Southampton docks for working up an American Boat Special.

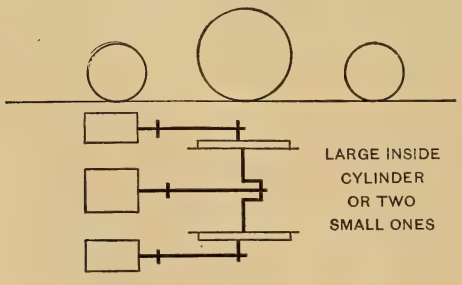


FIG. 4.—AN EARLY THREE-CYLINDER DESIGN, 1846

2.—BALANCED LOCOMOTIVES

George Stephenson and William Howe, of valve-gear fame, are responsible for the first locomotives in which the object was to obtain a more regular turning effect and a balanced engine by the use of three cylinders. Letters patent were taken out in 1846, and though the particulars available are very meagre, it is believed that two engines were built soon after. Fig. 4 indicates the essential features. The cylinders, two outside and one inside, drove on to one axle. A noteworthy point is that, according to the letters patent, the inside cylinder was of large dimensions,

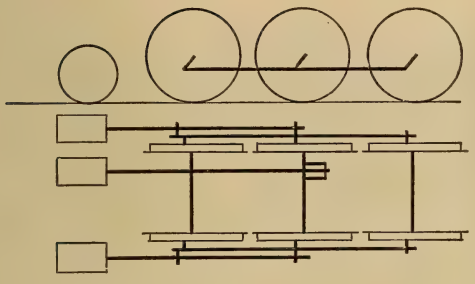


FIG. 5.—DIAGRAMMATIC LAYOUT OF THE BALDWIN THREE-CYLINDER ENGINE

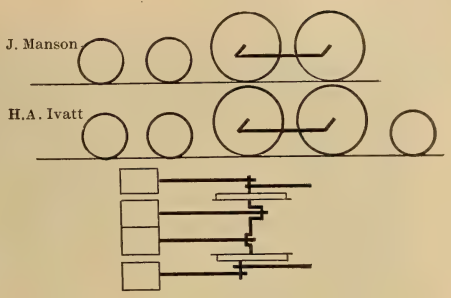


FIG. 6.—DIAGRAM OF FOUR-CYLINDER ENGINES DESIGNED BY MESSRS. MANSON AND IVATT

though it was also stated that two smaller cylinders may be employed instead. Various rules were laid down as to the angles between the cranks, but it is not necessary to consider them now.

In recent years several locomotives have been built in which three or four cylinders were employed, acting upon one axle at various angles. In 1894 three engines, see Figs. 3, 5 and 7, each provided with three cylinders driving at angles of 120°, were built to the designs of Mr. John B. Smith at the Baldwin Works, Philadelphia, for the Erie & Wyoming Railroad. These engines were peculiar in that the inside cylinder was not centrally arranged, as can be seen in Figs. 5 and 7.

A four-cylinder engine of this class, Fig. 6, was, in 1897, put in service by Mr. Manson on the Glasgow & South-Western Railway, the four cylinders, two inside and two outside abreast, all driving on one axle at angles of 90°. This engine is still in service, and although it has a good record, it has not been duplicated. The inside cylinders were 14½ inches by 26 inches, and the outside cylinders, 12½ inches by 24 inches. The driving wheels were 6 feet 9 inches in diameter. In 1897 also Mr. F. W. Webb built an engine,—"Iron Duke,"—with four high-pressure cylinders driving one axle, as a trial companion to his first four-cylinder compound engine. This engine was soon after converted to a compound engine, and renamed "Jubilee."

An engine with the same cylinder arrangement, but of large dimensions, has been recently built by Mr. H. A. Ivatt for the Great Northern Railway. No records of its work are yet available.

The latest instance of the use of three high-pressure cylinders is provided by Mr. J. Holden's huge ten-coupled tank engine for the Great Eastern Railway. This engine was described at some length

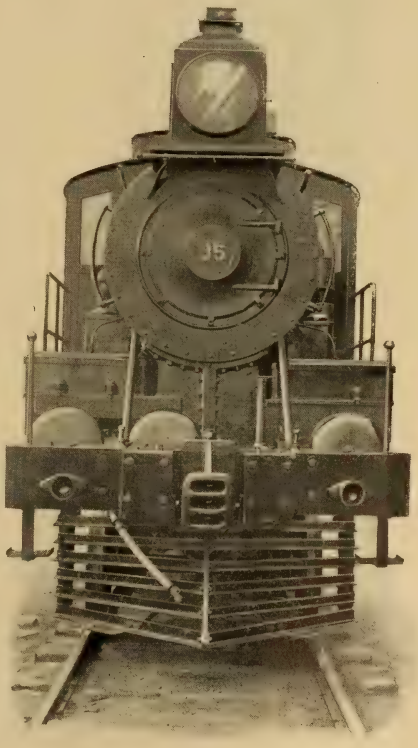


FIG. 7.—A FRONT VIEW OF THE ENGINE SHOWN IN FIG. 4. THE THREE CYLINDERS ARE HERE CLEARLY SHOWN

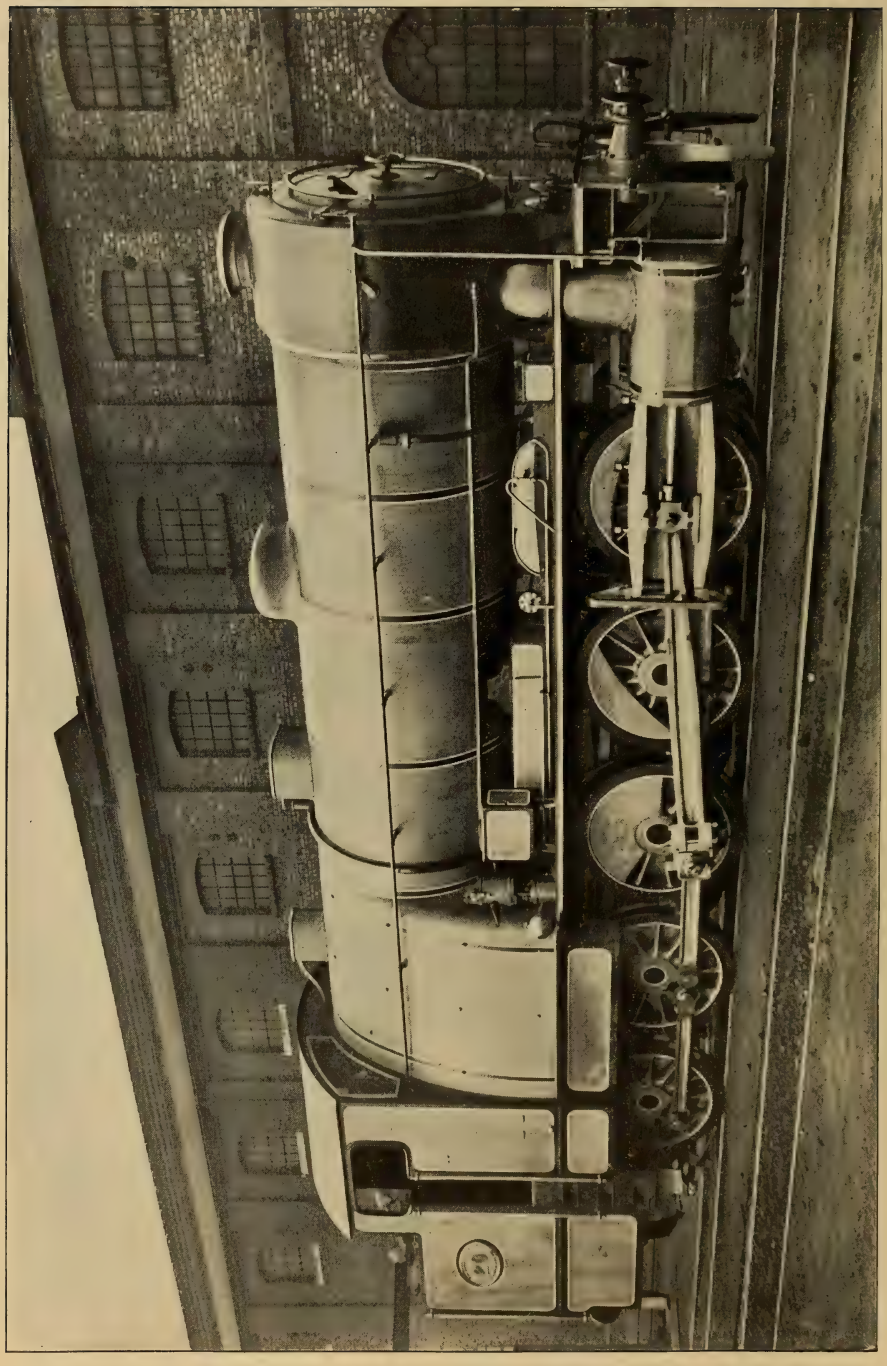


FIG. 8.—THE GREAT EASTERN RAILWAY DECAPOD. THREE CYLINDERS, NON-COMPOUND, 18½ × 24 INCHES. TOTAL WEIGHT, 78 TONS. DESIGNED BY MR. JAMES HOLDEN, M. INST. C. E., LOCOMOTIVE SUPERINTENDENT OF THE GREAT EASTERN RAILWAY, LONDON.

in an article in this magazine for May, 1903, by Mr. Holden himself, and to this it would be interesting to refer at this time. Fig. 8 is a general view of anti-hammer-blow locomotive, built for company promoting or similar purposes in the United States in the eighties, in which return cranks were used both for

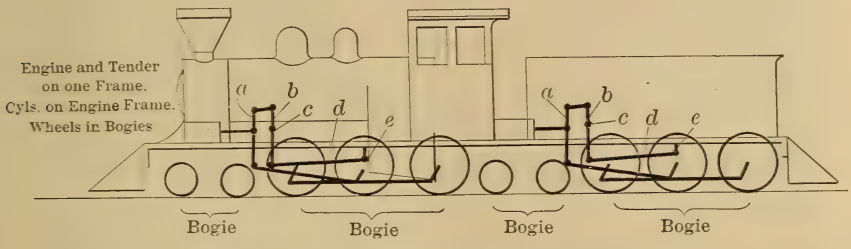


FIG. 9.—F. W. JOHNSTONE'S DESIGN FOR THE MEXICAN CENTRAL RAILWAY, 1886. ENGINE AND TENDER ON ONE FRAME

the locomotive, which represents a somewhat startling departure from British practice. The cylinders are abreast, the two outside ones driving the third axle, while the inside cylinder drives the second axle, the inside connecting-rod working round and embracing the slightly cranked first axle.

The engine was designed to attain a rate of speed of 30 miles an hour in as many seconds, and the records of its work will be attentively followed by all engineers.

So much for what may be termed orthodox practice in regard to multi-cylinder balanced locomotives, but there have also been two locomotives in which the cylinders were arranged in a decidedly impractical fashion. In 1861 Mr. John Haswell designed an engine,—the "Duplex,"—for the Austrian State Railways, having four outside cylinders acting in pairs on return cranks at each side. This engine is illustrated in Figs. 11 and 12. It was shown in London at the exhibition of 1862. The four cylinders were each 10⅞ inches in diameter, with a stroke of 24⅞ inches, and the driving wheels were 6 feet 9 inches in diameter. A fitting companion for the "Duplex" may be found in the Shaw

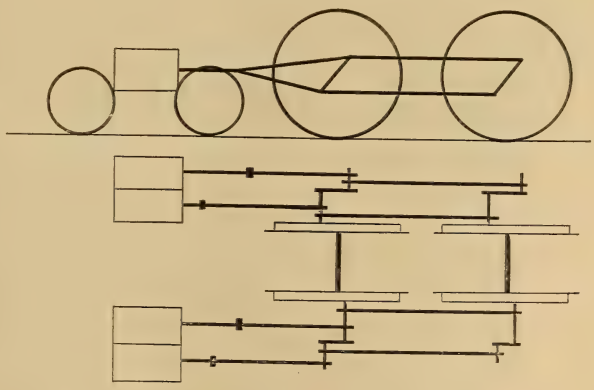


FIG. 10.—THE SHAW ANTI-HAMMER-BLOW LOCOMOTIVE, 1885

the connecting and the (double) coupling rods. In the Austrian engine the cylinders were inclined one above the other, and in the American engine, Fig. 10, they were side by side in each pair. It is said of the Shaw engine that "she was forever breaking pins," and probably the "Duplex" was similarly distinguished; at any rate, whether the engines were "balanced" or not, we should consider the remedy worse than the disease.

3.—HEAVY PULLERS

A pet theme with engineers whereby additional power may be provided in a locomotive has been the utilisation of the tender for tractive purposes. The earliest examples of steam tender loco-

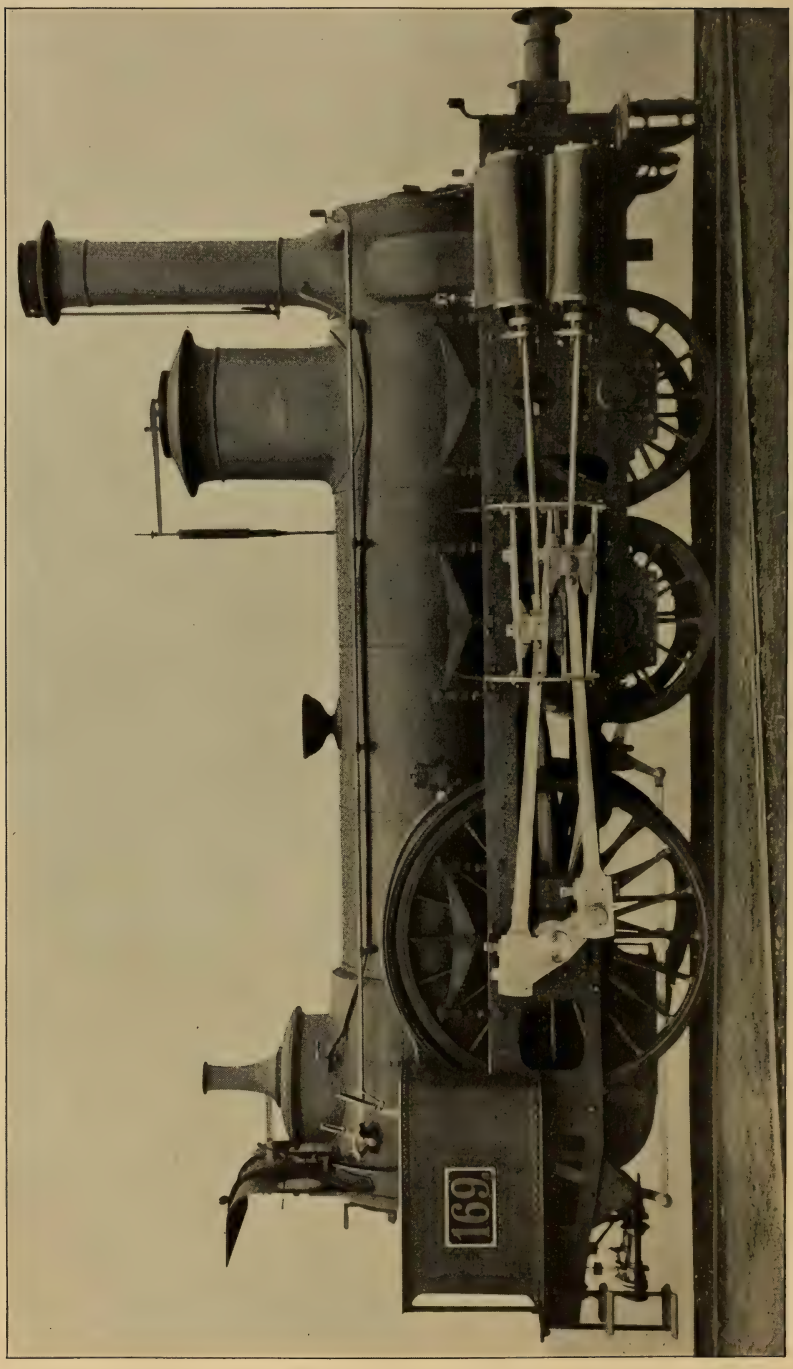


FIG. 11.—HASWELL'S BALANCED ENGINE "DUPLEX," 1861, ON THE AUSTRIAN STATE RAILWAYS

motives were used on the Lyons & St. Etienne Railway in France in 1843, but little is known of these. In 1863, on the Great Northern Railway, some steam tender locomotives having six-coupled wheels on the tender were put in service by Mr. Sturrock. One of these is shown in Fig. 13. Eventually about fifty of them were in use, and even more were ordered; but although successful mechanically, the tenders of all of them were shortly after dismantled, as the trains hauled were unwieldy and too long for the sidings, and, besides, the drivers, as is hardly to be wondered at, objected to have two engines to attend to, even with a boiler sufficiently large to supply steam for both.

In 1867 two six-coupled goods engines with six-coupled steam tenders, closely resembling those of Mr. Sturrock, were supplied by what is now the Alsacian Works (La Société Alsacienne) to the Eastern Railway of France. These engines are still at work with ordinary tenders, and the steam tenders have long since been provided with boilers, and are doing service as shunting engines at Belfort Station.

In 1886 Mr. F. W. Johnstone,—an engineer with a decided reputation for novelties,—designed for the Mexican Central Railway a queer steam-tender "articulated" locomotive. Fig. 9 shows the principal features of this strange machine in skeleton form. The boiler and tender are on one continuous rigid frame, not separate, as usual, and the six-coupled wheels of both engine and tender are in bogie frames, there being, in addition, two four-wheel trucks, as shown. The cylinders are

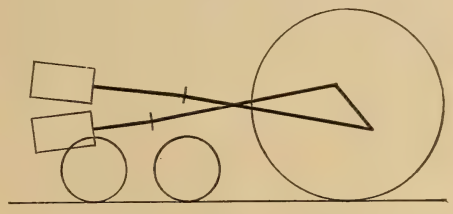


FIG. 12.—THE "DUPLEX"

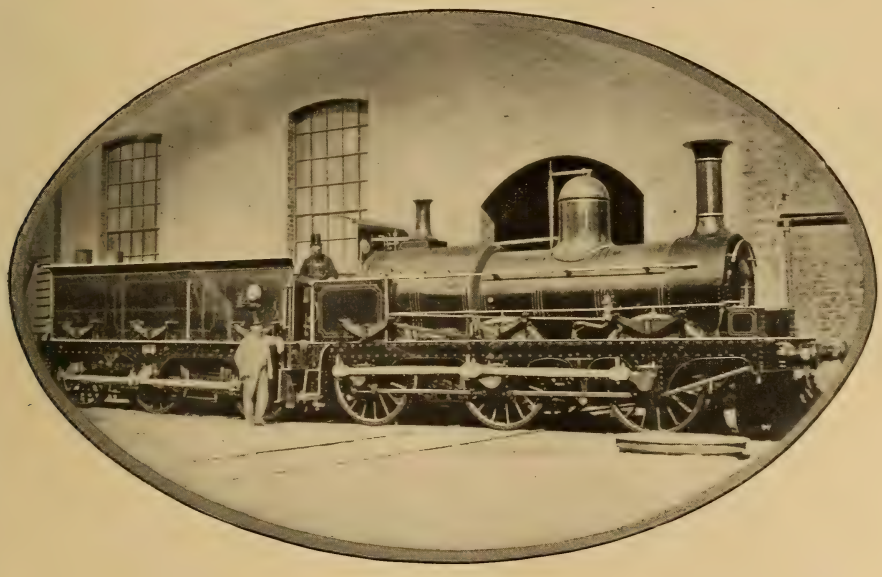


FIG. 13.—GOODS ENGINE ON THE GREAT NORTHERN RAILWAY, WITH ARCHIBALD STURROCK'S STEAM TENDER

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four in number, two in front and two in the cab, all being fixed on the frame. To connect with the driving wheels, each cross-head is fitted on a lever *a*, the lower end of which carries one end of the connecting-rod; at the upper end each lever *a* is linked to a rocking lever *b*, which oscillates on the fulcrum *c* and

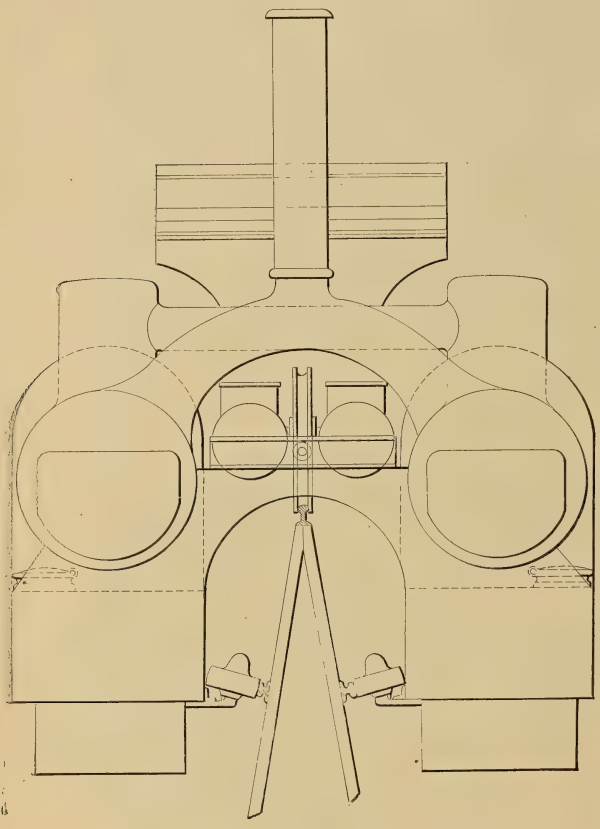

FIG. 14.—MALLET'S SINGLE-RAIL LOCOMOTIVE

is connected by the rod *d* to a fixed pivot *e* on the bogie frame.

Normally the lever *b* and the rod *d* are rigid, and the lever *a* transmits power directly to the driving wheels, with an increase in the stroke due to leverage. When, however, the engine is on a curve the rod *d* causes movement of the lever *b*, and through the link also of the lever *a*, to compensate for the alteration in the relative positions of the cylinders and the wheels. The pivotal connections between the various rods and levers are suitably constructed to admit of movement of the parts in planes inclined to one another, as becomes necessary in practice.

Much has been heard of late years of the wonderful possibilities of the "mono-rail" railway, but it is not generally known that in Ireland there has been in existence since 1888 a short railway of this character, the locomotives for which require attention in this section of the subject.

The Listowel & Ballybunion Railway is ten miles long, and has curves of very small radius and some steep gradients. Its permanent way consists of a single rail supported on trestles, and the locomotives and rolling stock hang on either side of the central rail. The locomotives have two small boilers, side by side, and two cylinders driving three coupled wheels between them. The tender is on two wheels, which are coupled and provided with steam cylinders, to be used, however, only on steep gradients as auxiliaries to the main engine, as the boilers can supply sufficient steam for all four cylinders only for short periods.

These engines were designed by Monsieur A. Mallet, so well known in connection with the early compounding of locomotives, and were built by the Hunslet Engine Company, Ltd., of Leeds, England. The cylinders are 7 inches in diameter, with a stroke of 12 inches, and the driving wheels are 3 feet 3 inches in diameter. The usual speed is about six or seven miles an hour.

Figs. 14 and 15 show, in end elevation and in diagrammatic plan, an engine of this type as described in M. Mallet's patent specification. Mr. F. B. Behr, whose name is so familiar in connection

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with recent mono-rail schemes, is also associated with M. Mallet in the matter.

4.—DOUBLE LOCOMOTIVES

In many places, and especially on mountain and narrow gauge roads, a

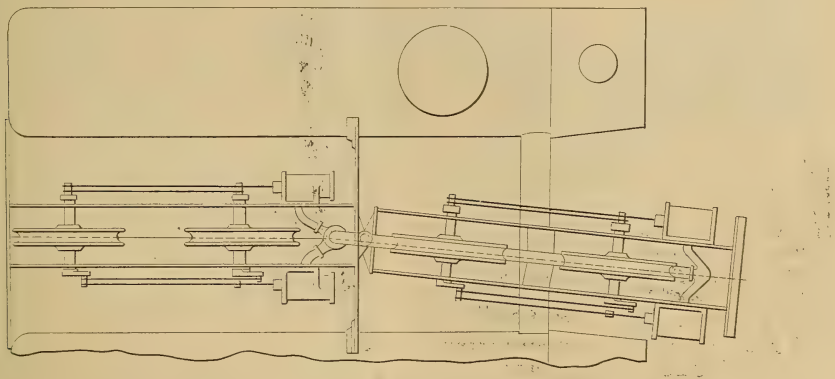


FIG. 15.—A HALF PLAN OF MALLET'S SINGLE-RAIL LOCOMOTIVE

powerful machine is required, while it is not possible to produce it on ordinary lines without unduly multiplying axles close together or using excessive loads per axle. The remedy has been found in the use of "double" locomotives. These are of two distinct classes, both in fairly common use in many parts of the world. In the one class must be placed those locomotives in which

there being one boiler over the whole. In almost every instance, too, the engines are "articulated,"—to use a very expressive word derived from the French, which is in general use to describe engines of these types,—that is, the two sets of cylinders, wheels, etc., are mounted on bogie frames pivotally connected to the boiler or boilers.

The original idea of the double locomotive is generally attributed to Horatio Allen, a name well known in American locomotive history, who, in 1832, built some locomotives for the South Carolina Railroad having two boilers joined end to end, with a large fire-box in

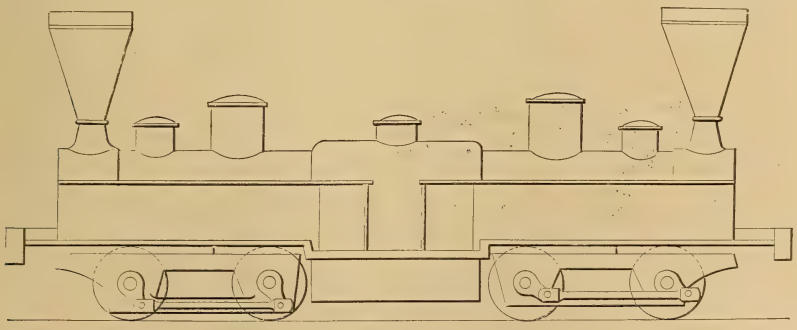


FIG. 16.—DOUBLE BOGIE LOCOMOTIVE "SERAING," 1851

double boilers, as well as double sets of cylinders, wheels and motion are employed; and in the other, engines with double sets of cylinders and wheels only,

common. Only two cylinders were used, one for each pair of drivers at the ends of the engine. In 1852, however, a four-cylinder double engine, usually

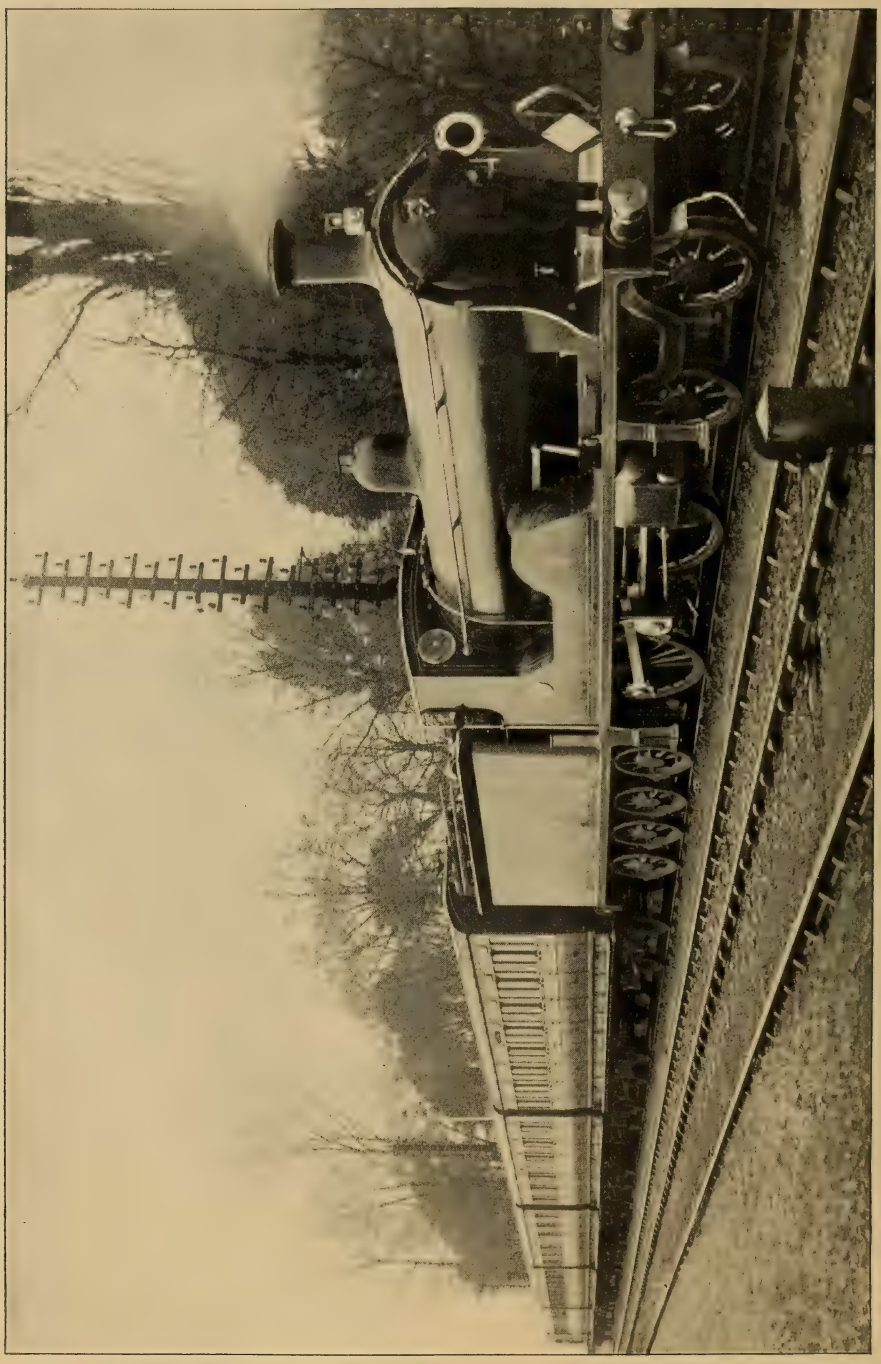


FIG. 17.—FOUR-CYLINDER SIMPLE LOCOMOTIVE OF THE LONDON & SOUTH WESTERN RAILWAY ON THE AMERICAN BOAT "SPECIAL" OUTSIDE SOUTHAMPTON

PHOTO BY G. F. TYAS

considered the first of the type, was designed by William Günther, of Vienna, and built by Messrs. John Cockerill & Co., of Seraing, Belgium, for competition on the Semmering Incline,—the bugbear of Austrian railways,—of the Vienna & Trieste Railway.

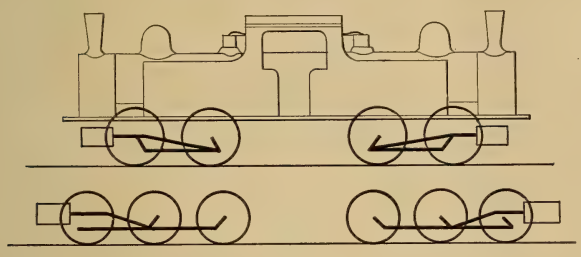


FIG. 18.—THE FAIRLIE TYPE OF DOUBLE LOCOMOTIVE

As will be seen from Fig. 16, which illustrates the general design of this engine, there were two boilers and one large fire-box,—the steam space extended right through,—supported on two pivoted bogie trucks, each with four coupled wheels driven by two inside steam cylinders. This engine, the "Seraing," was acknowledged to be the best of all those submitted for trial, and was the only one which satisfied the conditions laid down; but none of the trial designs were adopted, and the further history of this engine is unknown, nor were any others built by the same or other builders for many years.

In 1865 Mr. Fairlie revived the double locomotive, this time to endure, and the first of his engines, the "Progress," was put in service on the Neath & Brecon Railway. The main features are the same as in the "Seraing," except that the cylinders are outside, as in all Fairlie double engines. Since that date the design has been very generally adopted, and these engines are to be met with in all quarters of the globe. They range from light 12-ton engines, such as are used on the French narrow-gauge military railways, and for the Decauville Works portable railways, to 92-ton and even heavier engines, as used in Mexico, New Zealand, and Australia. In more recent years the compound principle has been applied to them.

A good example of a Fairlie engine may be found on the Ffestiniog narrow-gauge railway in Wales. The general features of this design are indicated in Fig. 18. The smaller engines have four-wheeled bogies, but in the larger ones six-wheeled bogies are employed.

In some parts of the world it is usual to couple separate locomotives together, back to back, and to connect the driver's gear so that he can operate both engines together when necessary. A few engines also are in use in which a double-ended tender is placed between two engines, the whole being arranged to operate as one combination. Such designs are not strictly double locomotives,

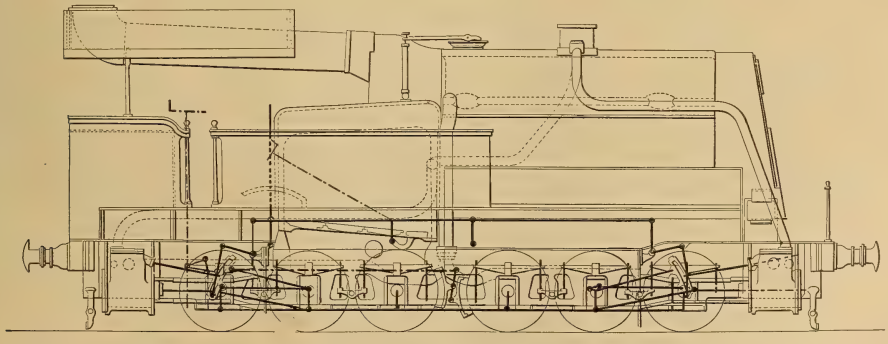


FIG. 19.—PETIET'S GOODS ENGINE, FOUR CYLINDERS, ON THE NORTHERN RAILWAY OF FRANCE

but they merit notice here. The alternative practice, and that which is the more general, consists in using one large boiler over two sets of wheels and cylinders and motion. Only one type of engine is known in which the wheels are not in a bogie frame and was divided into two six-coupled, two-cylinder units, and provided with boilers of the ordinary type. These forty engines are still in use as shunting locomotives.

In the Meyer "articulated" type of locomotive the wheels are arranged in

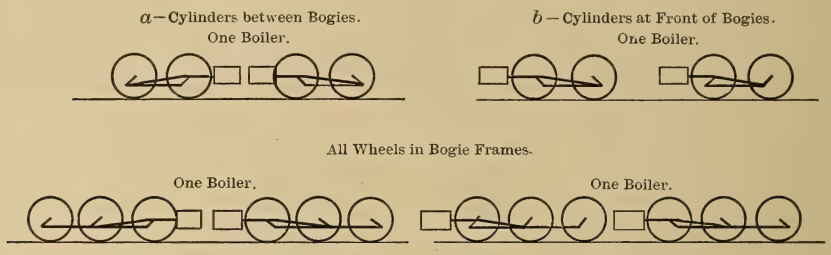


FIG. 20.—THE MEYER ARTICULATED TYPE. FOUR CYLINDERS

the engine is not, consequently, flexible. This example is provided by M. Pétiet's goods locomotives for the Northern Railway of France, the companions to his queer passenger engines already described and illustrated in Fig. 2. These tank engines, Fig. 19, have twelve wheels in two sets of six, each provided with a pair of cylinders supplied with steam from one boiler of the same design as that used on the passenger engines. All the axles are on the one two, four or six-wheel bogies, on which the boiler is supported, Fig. 20. The first of these engines,—"L'Avenir,"—was built in 1869 for the Hérault State lines, but was used for some time on the Northern Railway of France. This engine is shown in Fig. 21. It has been followed by a large number of similar ones, though of widely varying dimensions.

Usually the Meyer engines are tank engines, but there are many tender en-

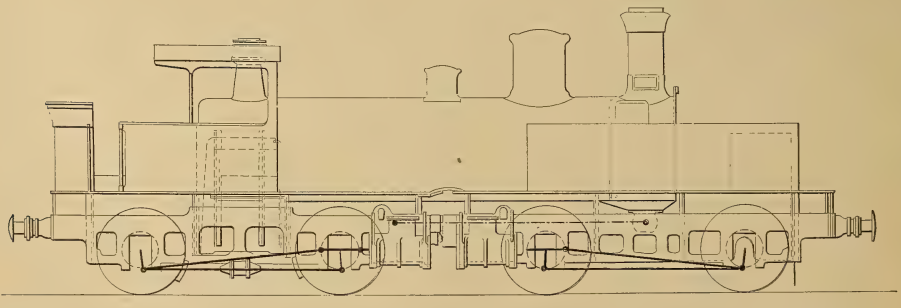


FIG. 21.—A MEYER FOUR-CYLINDER ENGINE ON THE NORTHERN RAILWAY OF FRANCE

framing, and the whole wheel base is rigid.

Ten engines of this design were built in 1863, and ten more, differing from the early ones in many details, were put into service in 1867. During the years 1871 to 1874 each of these engines gines in use on this system. It will be noted, on reference to Fig. 21, that the cylinders are close together and between the two bogies. In some engines, however, the cylinders are disposed in front of each bogie, as shown in Fig. 20.

In later years engines of this type have

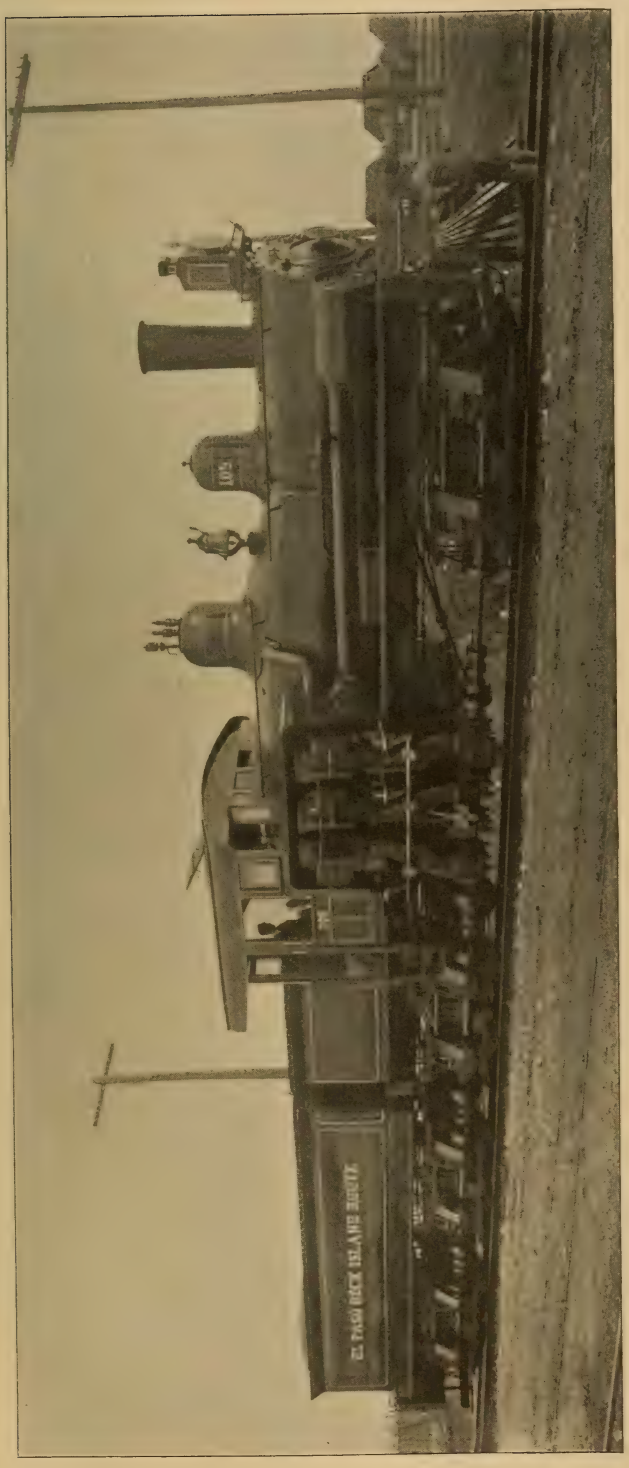


FIG. 22.—A HEAVY SHAY LOCOMOTIVE, BUILT BY THE LIMA LOCOMOTIVE & MACHINE CO., LIMA, OHIO, U. S. A.

been compounded, and the type has been adopted even more extensively than before.

5.—THE SHAY LOCOMOTIVE

The Shay locomotive, Fig. 22, built by the Lima Locomotive and Machine Company, of Lima, Ohio, U. S. A., belongs to a totally distinct category from anything which has gone before. It is designed to haul heavy loads over sharp curves, and it is claimed for it, and justly, too, that, weight for weight, it is the most powerful locomotive on the market. In these engines four, six, or eight wheeled trucks are used to support the engine and tender, and all the wheels are utilised as drivers, being driven through bevel gearing by a longitudinal shaft, in universally jointed sections, operated by a three-cylinder vertical engine.

The driving shaft is fitted along one side of the engine, with the cylinders located at the side of the firebox, and this gives a one-sided construction which is compensated for by placing the boiler out of the centre line towards the other side.

These are probably the most flexible engines built, and are adapted for use on logging or other

roughly laid roads. It is also claimed for them that not only is the weight per axle comparatively small, but the bogies may be arranged considerable distances apart, so that they can be used over light bridges, the weight on any one section of the bridge not being seriously great, as would be the case with an equally powerful engine of the ordinary type.

These engines, of which over a thousand have been supplied to the United States, Canada, South America, Mexico, and Australia during the last twenty years, vary in weight from 10 to 150 tons, the lightest with two, instead of three, 6 in. x 10 in. cylinders and eight wheels, and the heaviest with twelve and sixteen driving wheels with three cylinders. It is only the very lightest Shay engine which has two cylinders, the use of three cylinders being the rule.

Fig. 22 illustrates the heaviest Shay engine yet built, though others equally powerful are on order. This particular engine is for the El Paso Rock Island route in New Mexico, and was built to satisfy the following conditions:—To operate on 60-pound rails on the section from Alamorgordo to Cox Cañon, a distance of 31 miles, with a total elevation between terminals of 6000 feet, over grades ranging from 3 to 6½ per cent. On one 8-mile section, with numerous curves, the grades range from 4.5 to 5.2 per cent, and there is almost half a mile at 6.5 per cent.

The weight on the drivers of this locomotive is 291,000 pounds, while the latest large engines of the Atchison, Topeka & Santa Fé Railroad, turned out by the Schenectady works of the American Locomotive Company,—the heaviest engines in the world,—have a weight of only 232,000 pounds available for adhesion. The Shay engine has the advantage of these engines, in spite of their greater weight, in that it makes use of the tender for adhesion. This is the secret of its great power. The wheel base of the Shay locomotive is flexible and measures 57 feet 4 inches in length. The weight on each axle is only 36,250 pounds.

The locomotive is built for use on lines where the ordinary engine would almost certainly leave the rails, and they are thus especially adapted to lines in lumbering and mining districts. Even the largest engines are said to be capable of taking curves of 100 feet radius, while the small engines will work round 45-foot curves.

Although the Shay engine is unique, there are a few locomotive types in which gearing is employed for driving a series of bogies, the cylinders being applied in various ways; but none of these, so far as is known, have more than two cylinders, and they are, therefore, outside of the province of this article.

Part II, dealing with "Three-Cylinder Compound Locomotives," will appear in the January number

THE SCIENCE OF STEAM GENERATION

By F. J. Rowan, Assoc. M. Inst. C. E.

THE most familiar phenomena often contain for us, and may convey, the most profound instruction in the facts of science; but too frequently that is passed by in favour of the utilitarian aspect. For example, the ordinary domestic fire-grate is rich in lessons on combustion and the formation of flame; but who that wants to make use of the warmth, or to enjoy the cheerful glow of the fire ever thinks of stopping to analyse the processes which are going on before his eyes.

So with the boiling of water. The homely kettle is the exponent of several facts or principles which are of very great interest and importance. The conduction of heat from the fire through the metal to the water, the distribution of heat throughout the liquid, involving its expansion and circulation, with the ultimate change of physical state in the formation of steam, as well as some idea of the elastic force of steam, are all exemplified and almost unheeded day by day. The kettle, however, introduces us to only one method of steam formation, namely, that which takes place in open vessels, at a slow rate, or in comparatively small volume, and at atmospheric pressure.

When we come to consider the rapid formation of steam in considerable volume under high pressure we are introduced to a far more complex physical process which demands suitable conditions and produces a considerable variation in the phenomena observed. In the one case we have a natural action, proceeding in a leisurely, normal way; in the other, an artificial process, which must be conducted on an enlarging scale, and, in these days, with greatly increased acceleration of speed. Naturally, with such a process there are additional elements, all of which must find a place in the final result produced, and these are the question of, the weight of, and space occupied by, the boilers, the weight and cost of fuel and water consumed, and facility of management and preservation; and all these bring into view the subject termed "efficiency," which furnishes a strict rule by means of which the performance of every boiler must in the end be tested and judged.

Steam generation is the result of several processes which are carried out with a boiler or generator of suitable design. These processes are,—

1.—Combustion, which means the combination of the oxygen of the air with the carbon, hydrocarbons, and hydrogen of coal or other fuel, at a suitable temperature.

2.—Transmission of heat.

3.—Change of the physical state of the water in the boiler, in which is involved the phenomenon of latent heat.

The science of steam generation embraces, or is the sum of, those physical laws which govern all the actions involved in the form and functions of the boiler. It is the practical application of this knowledge to the purpose mentioned which alone can guide us to the best form of boiler, so that the highest result may be obtained; and in order that we may appreciate the proper relation of the various processes concerned in steam generation to one another, and to the result finally arrived at, we must adopt a comprehensive view of the subject. To have this we must begin with

a correct fundamental idea which is secured by considering the steam boiler as a heat engine to which we apply the reasoning applicable in the case of every other form of heat engine.

It is curious that in the past as a general rule boilers seem to have been considered from every other possible point of view rather than this one. There were undoubtedly exceptions; but as far as the general practice is a guide, it has been customary to regard the boiler in the light of a structure or machine. In early days difficulties in manufacture and from imperfect materials, no doubt, seriously hindered the production of any but the most elementary forms; yet, at the same time, comparatively little effort seems to have been directed to the production of any others. The main idea of design was founded on the kettle as a pattern, and modifications of form were introduced from considerations of strength or of convenience of manufacture.

The requirements of a boiler were reckoned to be the providing of sufficient space to hold a mass of water, and sufficient space to receive and hold the steam, with a margin of strength to carry the working pressure. As regards the application of heat, the direct radiant heat of the glowing fuel or the contact of the flame was considered the great thing, the hot gases from the point of the extinction of the flame not being considered of much account. From imperfect knowledge of the facts of combustion, flame also was often incompletely formed either because of insufficiency of air supply or too speedy contact of the gases with the metal surface of the boiler, and thus followed additional loss of heat.

Although quaint inventors proposed stirring the water, in order to "open its pores," as they said, to the passage of the heat, or to inject small quantities of water successively into heated chambers, or to subdivide the water into small quantities by means of tubes or partitions, or to convey the heat through the masses of water by means of highly heated oil or by fusible alloys, and so on, proving that they to some extent appreciated the problem which was before them, yet no doubt these were considered, as inventors are still to a great extent considered, as visionaries and impracticable dreamers. At any rate, the "kettle" ideas survive in a considerable measure even to this day.

General practice, even with the kettles, has, however, immensely improved, and, thanks to the labours of enthusiasts like the late Charles Wye Williams, such knowledge as that of the main facts of combustion has become widely spread, so that very much better results are obtained and a high percentage of the potential heat of the fuel is often usefully applied in raising steam.

The writer would here, nevertheless, raise a protest against the prevalent habit of making that one result the measure of the efficiency of a steam boiler. It gives information as to the use of the fuel, but conveys no hint of the proportions of the boiler or of the efficiency of its surfaces. The boiler may be from another point of view, five times too large or ten times too heavy; but the present statements of "efficiency" give no enlightenment on such points. The elements of the boiler, which are essential to the problem of really efficient steam generation, are carefully excluded from all present estimates of efficiency. This may be due to the fundamental idea of the boiler and its functions which has been adopted, but it is very evident that in the future this must be altered or added to.

In his lecture on "Gas and Caloric Engines," at the Institution of Civil Engineers, in London, probably the last lecture he delivered, the late Professor Fleming Jenkin showed that, in dealing with heat engines, the term "efficiency" can be used in several ways, of which he gave the following four examples:—

First, we may have what may be termed the "absolute efficiency,"—that is to say, the ratio between the indicated horse-power and the total quantity of heat which is generated by the fuel per minute. Denoting this efficiency by the letter E, we have $E=\frac{I.\ H.\ P.}{H}$

Second, there is what may be termed the "ideal efficiency" E_i. This is the ratio of the difference of the absolute temperatures $(T_1 - T_2)$, between which a heat engine works, to the higher of these temperatures, and represents the utmost proportion of the total heat which can be converted into work in an ideal engine,—thus

$$E_i = \frac{T_1 - T_2}{T_1}$$

Third, E, compared with E_i, gives the "relative efficiency," E_r, thus

$$E_r = \frac{E}{E_i}$$

Fourth, we may compare the work which a given engine might perform theoretically, according to an indicator diagram calculated on certain hypotheses, with the heat generated by the fuel per minute. This would be the "theoretical efficiency" of that engine, E_t. If $H P_t$ denotes the work calculated as described, then $E_t = \frac{H P_t}{H}$

Now the expression of boiler efficiency which is in use to-day bears a relation only to the first of these, and so represents the ratio between the quantity of water evaporated (reckoned as heat) and the total quantity of heat generated by the fuel in a given time. What is wanted is an expression of the heat transmitted (in thermal units or in pounds of water evaporated) per unit of heating surface per unit of time compared with the total heat yielded by the combustion of the fuel in that time; and in order to properly classify such a result we need a standard or theoretical efficiency on the lines of Professor Jenkin's fourth, in which $H P_t$ should become $H T_t$ or some other symbol expressing the maximum heat transmission possible per unit of surface.

Attention is here directed to Fig. 1, which is an illustration used by the late Sir William Anderson to give a graphic representation of the theory or principle of the heat engine.

It represents a hillside rising from the sea. Some distance up there is a lake L fed by streams coming down from a still higher level. Lower down the slope is a millpond P, the tail-race from which falls into the sea. At the millpond is established a factory, the turbine driving which is supplied with water by a pipe descending from the lake. The

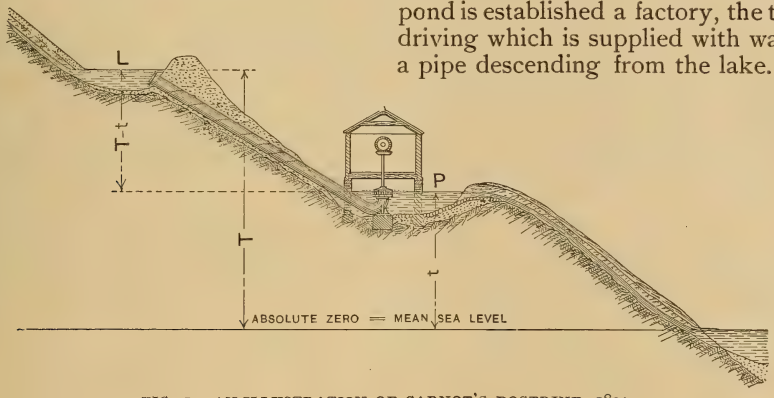


FIG. 1.—AN ILLUSTRATION OF CARNOT'S DOCTRINE, 1824

datum line is the mean sea level, the level of the lake is T, and that of the millpond is t; Q is the weight of water falling through the turbine per minute. The mean sea level is the lowest level to which the water can possibly fall, and hence its greatest potential energy, that of its position in the lake, is $Q T = H$. The water is working between the absolute levels T and t; hence, according to Carnot, the maximum effect W to be expected is $W = H\left(\frac{T-t}{T}\right)$; but $H = Q T$; therefore, $W = Q T\left(\frac{T-t}{T}\right)$ or $W = Q\,(T-t)$, that is to say, the greatest amount of work which can be expected is found by multiplying the weight of water into the clear fall, which

is, of course, self-evident. It will be clear that if we want to increase the effect produced by a given weight of water, without in any way improving the turbine, we can do so either by collecting the water higher up on the hill and thus increasing T, or by placing the turbine lower down nearer the sea and thus reducing t.

Applying this to a heat engine, such as a boiler, the sea level represents the absolute zero of temperature, and, similarly, T and t represent the maximum and minimum temperatures between which work is being done. Therefore, the "ideal efficiency" of such a heat engine will depend upon the production of the highest possible temperature in the furnace and the lowest possible temperature in the escaping waste gases. The problem before us is to produce these results with the most efficient and economical apparatus.

The first step brings us face to face with the interesting phenomena of combustion. The writer shall take it for granted that these, involving the main facts of the chemistry of combustion, are generally understood, and shall direct attention only to one or two important points connected with the subject. In Table I are given the number of British thermal units due to the combustion of the substances mentioned in the first column, the weight of the products of combustion, their mean specific heat, and the temperature theoretically produced when only the exact quantity of oxygen or air necessary for chemical combination is used. These temperatures are hardly ever produced in practice on account of the employment of an excess of air, as well as because of incomplete combustion, and the last three lines of the table show the result when carbon is burned with air only to the monoxide (CO), and when 20 per cent. and 50 per cent. excess of air are used in burning to carbonic acid (CO_2). Such results are represented graphically in Fig. 2, which the writer has borrowed from a lecture by the late Sir William Anderson, in which curves are given to show the theoretical temperatures on the absolute scale for carbon and for petroleum (composed of 0.84 carbon and 0.16 hydrogen) when one and one-half, two, two and one-half and three times the theoretical quantity of air are employed.

Thus, for solid carbon, taking as a starting point 5150° F. absolute* as the theoretical temperature of combustion with 12.2 pounds of air per pound carbon, the lower curve shows the calculated temperatures with successive additions of air, making the total amounts 18.3, 24.4, 30.5, and 36.6 pounds per pound of carbon, these quantities being set up as vertical ordinates to the base line which represents absolute zero. The horizontal lines represent various degrees of temperature on the absolute scale, the shaded portion showing the limits within which steel was supposed by the late Sir William Siemens to melt.

The upper curve represents the same process in the case of the petroleum

TABLE I

Conditions of Combustion	Number of B. Th. Units Produced	Weight of Products of Combustion	Mean Specific Heat of Products of Combustion	Temperature Produced
1. 1 lb. Carbon burnt to CO_2. Pure oxygen supplied	14,000	$3\frac{2}{3}$	0.216	$\frac{14{,}000}{3\frac{2}{3}} = 17676°$ F
2. 1 lb. Carbon burnt to CO, Pure oxygen supplied	4,000	$2\frac{1}{3}$	0.243	$\frac{4{,}000}{2\frac{1}{3} \times 0.248} = 6912°$
3. 1 lb. Carbon burnt to CO_2, Oxygen supplied in air	14,000	13	0.237	$\frac{14{,}000}{13 \times 0.237} = 4545°$
4. 1 lb. Carbon burnt to CO, Oxypen supplied in air	4,000	7	0.254	$\frac{4.0^{-}0}{7 \times 0.254} = 2249°$
5. 1 lb. Carbon burnt to CO_2. Oxygen supplied in air 20 per cent. in excess	14,000	15 2-5	0 237	$\frac{14.000}{15.4 \times 0.237} = 3836°$
6. 1 lb. Carbon burnt to CO_2, Oxygen in air 50 per cent in excess	14 0 0	19	0.237	$\frac{14.0^{-}0}{19 \times 0.237} = 3109°$

*Sir Wm. Anderson's calculation of temperature.

$$T = 520° + \frac{14544 \text{ units}}{13.2 \text{ lbs.} \times 0.238} = 5150° \text{ absolute.}$$

mentioned, only in this case the theoretical minimum of air required is 10.32 pounds per pound of oil, and the successive additions are in multiples of that quantity. These higher temperatures produced by the combustion of oil are in favour of its economy as a fuel for steam raising, although this point has not been used by the advocates of liquid fuel.

By transferring heat from the waste escaping gases to the incoming air to be used for combustion, higher temperatures of combustion are obtained than those due to the use of air at the atmospheric temperature. We can obtain a rough idea of this effect by taking the case mentioned on Line 5 of Table 1, and supposing the air to be thus heated to 400° above the normal atmospheric temperature. The result would be that $14.4 \times 400 \times 0.238 =$ about 1371 units of heat would be added to the furnace per pound of carbon burnt, and the temperature of combustion would then be $\frac{14{,}000 + 1371°}{15.4 \times 0.238} = 4211°$ F., or an increase of 375° over the temperature 3836° produced without the preliminary heating of the air.

Where, however, heat is required in the waste gases in order to give them "ascentional force" (so-called) for the production of chimney draught, a limit is very quickly placed on the amount of the heat which may be transferred for the purpose just mentioned; but with mechanically produced draught, or what is called "forced combustion," that restriction is removed, and, given suitable apparatus, we may bring the temperature of the waste gases down to that of the atmosphere if we please. Forced combustion also enables us to produce a much larger volume of heat in a furnace of given size per minute or per hour than would be possible with the chimney draught ordinarily available, and rates of combustion up to 100 pounds of coal per square foot of grate area per hour are known with various degrees of pressure of air supply up to 9 inches of water column.

There is still one method by which the combustion temperature (the level of the lake, T, in Fig. 1) may be elevated, and that is by increasing the pressure under which the operation is carried on. Although the correctness of this method has its foundations in the dynamical theory of heat and the laws which gov-

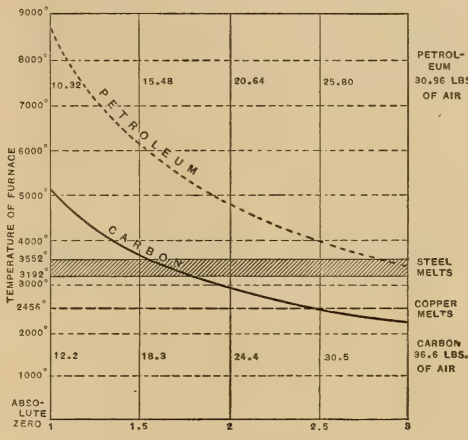


FIG. 2.—EFFECT OF QUANTITY OF AIR ADMITTED TO A FURNACE ON ITS TEMPERATURE

ern the specific heat of gases, it has not yet found favour amongst engineers. But it is certain to be made use of sooner or later. If we look up a table of the specific heat of gases, we find that whilst under "constant pressure" the specific heat of air is 0.2374, nitrogen 0.2438, and carbon dioxide 0.2163, under "constant volume" these become,—air 0.168, nitrogen 0.173, and carbon dioxide 0.171. This means that if gases are allowed to expand while being heated, they will require more heat to raise their temperature than would be necessary were they confined to a limited space during the operation, when, of course, their pressure would increase.

This is consistent with dynamical laws, for a certain quantity of heat disappears or becomes latent in the work of expanding the gases, this quantity being available as sensible heat when the gases are not expanded or compressed. It is, of course, well known that when air is compressed in an air compressor its temperature is raised, although no heat has been applied during the operation, and that is the converse action which

shows the reappearance of the latent heat as sensible heat.

Now as applied to combustion, it has been shown that by conducting the process under a pressure of two atmospheres a temperature will be produced 715° higher than that obtained at atmospheric pressure, and a further rise of 493° would be realised by increasing the pressure to three atmospheres. It has also been shown that this method increases the proportion of carbonic acid in the gases. This method would certainly demand some alteration of the existing combustion arrangements, but the time is not far distant when the ordinary inside grate will be abolished for ordinary forced combustion, and in any case no merely mechanical difficulty can be allowed for any length of time to stand in the way of improvement.

Another point should be noticed here, and that is the question of the use of radiant heat from the incandescent or glowing carbon, as against the heating by convection which takes place by means of contact of the flame and hot gases with the boiler surfaces. Some people attach much importance to the radiation from the fire; but except in furnaces like those of Lancashire and Cornish and locomotive boilers, that importance is, to a great extent, a matter of imagination. Not only do the heat rays proceed in straight lines in all directions equally, but they may even be reflected from the very surfaces which we hope will absorb the heat. Moreover, certain experiments have shown that whereas in heating by radiation the rate of heat transmission in the apparatus employed ranged from 3820 to 8540 C. G. S. heat units per unit of surface per unit of time, when heating by convection occurred, the results were from 4700 to 16,050 heat units per unit of time.

I believe the best results will be obtained by confining the radiant heat to the combustion chamber, arranged so that the minimum of the heat rays will be directed in a useless direction, and thus making use of them to increase the temperature of combustion and the completeness of flame formation.

We come now to the second division of the subject, which deals with the utilisation of the heat produced and the lowering of the lower temperature level in the heat equation. Here we are concerned with the kernel of the subject of steam generation; for, important as combustion undoubtedly is, yet the determining factor of the problem before us has proved in some cases, and will prove generally, to be that of heat transmission. It is, however, a fact that although boilers are, and have been, designed with a view to convenience of stowage, to strength of the structure, to largely increased heating surface, to lightness, and to other points connected with their use, the best conditions for the transmission of heat have not as yet exerted any marked influence upon boiler design. This is remarkable because an observer, looking at the subject from the outside, must at once perceive that steam generation is primarily and mainly a question of heat transmission.

The difference between water in the liquid state and in the gaseous state (or in the form of steam) is merely a matter of heat. A comparatively small amount of heat suffices to raise the temperature of water from that of the atmosphere to 212° F.; but then 966 B. T. U., or degrees Fahrenheit per pound (the heat which becomes latent), must be added to the water before its physical state is changed, its volume as steam relatively to its former volume of water becoming about as 1600 is to 1. This steam has still the temperature of 212°, and although it might be supposed that much more heat, and, therefore, fuel, would be required to produce steam of, say, 300 pounds per square inch pressure, or about 415° F., yet that is not the case.

In Table II are given the temperatures of saturated steam at various pressures, these temperatures being stated in Centigrade degrees in Column 1, and the corresponding pressures in atmospheres in Column 2; in Column 3 is given the total amount of heat in Centigrade heat units necessary to raise unit weight of water from 0° C. to the

state of vapour at each temperature. From this table we can find the weight of water which the heat of 1 pound of carbon can raise from 0° C. to the state

TABLE II

I	II	III	IV
Temperature in Centigrade Deg.	Pressure in Atmospheres	Total Heat in Centigrade Units	Pounds of Water Converted into Steam per Lb. of Carbon
100	1	637	12.57
121	2.025	642	12.53
134	3.008	646	12.46
144	4.000	649	12.40
152	4.971	651	12.36
159	5.966	654	12.30
171	8.036	656	12.27
180	9.929	659	12.21
189	12.125	662	12.16
199	15.062	664	12.13
213	19.997	667	12.06
225	25.125	670	12.01
239	27.534	675	11.92

of vapour at any of these temperatures. We take 8050, which is the thermal value in Centigrade units of 1 pound of carbon, and divide it by the total heat for the temperature wanted. The writer has, therefore, added a fourth column to this table, in which the result is calculated out for all the pressures and temperatures given.

Thus $\frac{8050}{667} = 12.06$ pounds water raised from 0° C. and converted into steam of 19.997 atmospheres, or about 300 pounds per square inch, by the same amount of carbon. That is one of the secrets of the economy of high-pressure steam, because practically the same expenditure of heat produces such a vast difference in the amount of obtainable energy when that heat is intelligently applied.

Now, as the combustion of the fuel which furnishes us with this heat cannot take place in contact with the water,—in which it is unlike the combustion of the metals potassium and sodium,—we are at once confronted with the fact that the heat so yielded must be passed from the outside of some chamber to water on the inside,—that is, across some solid medium. That medium is either wrought iron, steel, or copper,—most frequently mild steel in ordinary practice; and if we inquire what is its capacity per square foot of surface for transmitting heat, we find that this is practically unlimited, unless interfered with by great thickness or some artificial resistance, such as a coating of scale or oil.

When we turn from this to inquire what is realised in practice with boilers, we find that in the year 1747 an inventor named John Payne, in describing his boiler to the Royal Society of London, announced that he had "rarefied" or turned into steam 90 gallons of water with 112 pounds of coal. This gave an evaporative rate of 8.03 pounds of water per pound of coal; but, unfortunately, we do not know the rate of evaporation per unit of surface.

Present practice with modern boilers rarely exceeds John Payne's result, and, measured per unit of surface, it reveals the astonishing fact that the average evaporation amounts only to from 2½ to 7 pounds, rarely more, and say exceptionally to 10 pounds of water per square foot of heating surface per hour, whereas the writer believes we have solid ground for maintaining that an evaporation of 50 to 80 pounds, and possibly of 100 pounds, per square foot of surface per hour can be obtained in regular practice with suitably designed boilers. Here, then, is a great opening for improvement, and in order to take advantage of it we must make ourselves acquainted with all that can be learned from investigations of the phenomena of heat transmission.

Many such investigations have been carried out, but the writer can refer to only a few which may be considered as more directly bearing on the subject here. The men who are interested in evaporators and feed-heaters have done a good deal of this work, and, in fact, most of the early experiments on heat transmission were carried out with steam or hot water as the source of the heat.

Of the pioneers the most distinguished was Péclet, whose "Treatise on Heat" proved a storehouse of information for many years. Most of his experiments, made with a view to determining the heat-transmission coefficient (or coefficient of conductivity) of various metals, were carried out by means of a simple apparatus in which the metal plate under experiment separated two compartments containing water. The water on

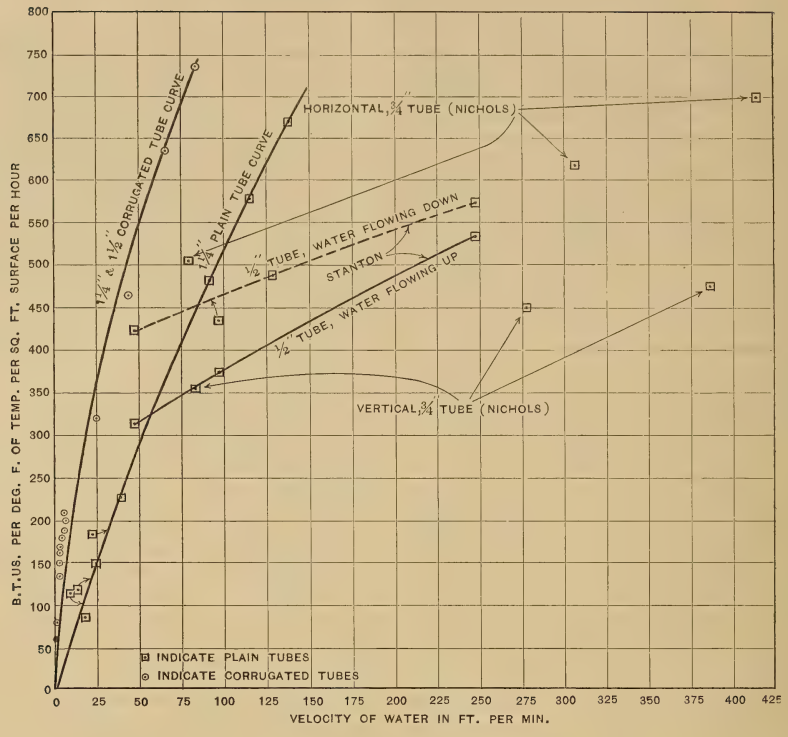

B.T.U.S. PER DEG. F. OF TEMP. PER SQ. FT. SURFACE PER HOUR
VELOCITY OF WATER IN FT. PER MIN.
HORIZONTAL, ¾" TUBE (NICHOLS)
¼" & 1½" CORRUGATED TUBE CURVE
¼" PLAIN TUBE CURVE
½" TUBE, WATER FLOWING DOWN
STANTON
½" TUBE, WATER FLOWING UP
VERTICAL, ¾" TUBE (NICHOLS)
INDICATE PLAIN TUBES
INDICATE CORRUGATED TUBES

FIG. 3.—HEAT ABSORPTION CURVES

one side of the plate was hot and on the other cold, and the experiment consisted in measuring the amount of heat transmitted in given time through the metal from the hot to the cold water. In each of the compartments apparatus was provided to give rapid motion to the water, Péclet having discovered that motion is a vital necessity to heat transmission. He also laid it down as an axiom that, especially where gases are employed, the motion of the currents should be in opposite directions over the two surfaces.

The effect of movement was also shown in experiments on cooling (which is, of course, heat transmission reversed) by Colding and B. C. Nichol, whilst the influence of increased velocity on heat transmission has been investigated by G. A. Hageman, Professor Louis Ser, Professor Osborne Reynolds, T. E. Stanton, H. G. Hudson, and perhaps some others, and has been shown to be profound. Some of the most notable results from experiments on heat transmission, where steam is the heating medium, were obtained by Mr. G. R. Lang, who communicated them to the Institution of Engineers and Shipbuilders in Scotland in 1889. These experiments were carried out in an apparatus which was a working size of one of the Weir evaporators, and the principal results obtained showed an evaporation of 101.14, 109.32, 118.75, 135.33 and 140.23 pounds of water per square foot of surface per hour, with temperature differences (between the steam and water) of 69.1, 75.7, 81.3, 99.7, and 106.7° F. The thermal units transmitted per square foot of surface per hour per 1° difference of temperature were 1324, 1329, 1334, 1286, and 1224.

Fig. 3 represents graphically some results obtained by Nichols and Stanton, in England, and by H. L. Hepburn and W. O. Hildreth, in America, in experiments with tubes, plain and corrugated, and in vertical and horizontal positions, with steam on one side and water on

the other. Such investigations have been carried out so thoroughly that formulæ have been developed by means of which the principal dimensions of feed-water heaters are calculated for a given duty.

Investigations of the phenomena of heat transmission where the heat is derived from flame or hot combustion products applied directly have been made by Hirsch, Blechynden, Bryant, and Witz with special apparatus; and many measurements of evaporation have been made with steam boilers.

In the special apparatus used by Hirsch the plate experimented with formed the bottom of a small boiler or cylindrical dish for the evaporation of water. A series of holes were drilled some distance into, but not through the plate, in two concentric circles on the fire side of the plate, and into these holes plugs of alloys were inserted having a range of melting temperatures from 230° to 842° F. From their behaviour in his experiments Hirsch concluded that sound and clean plates in a boiler could not be overheated as long as water was being evaporated from them at rates up to 75 pounds per square foot of surface per hour. He also investigated the effects of increased viscosity of the water, of incrustations, of flaws and joints in the plates exposed to the heat, and of coatings of oil and grease upon the rise of temperature in the plates at different rates of evaporation.

The form of apparatus employed by Hirsch was, with some improvements, adopted by Miss E. M. Bryant, B. Sc., in her investigations on "The Thermal Condition of Iron, Steel and Copper when Acting as Boiler Plates." This apparatus avoided the loss by conduction and radiation and the errors due to the fusible plugs in Hirsch's arrangement; but it had its own defects, the most prominent of which perhaps was the manner in which heat was applied to the plate. Naturally, Miss Bryant's endeavour was rather to attain permanent conditions of action than to reach maximum rates of transmission; nevertheless, she has plotted for us results giving rates of evaporation of from 30 to 70 pounds per square foot per hour, with the corresponding temperatures of the fire side of the plates obtained by means of thermo-electric junctions connected to a galvanometer. At 50 pounds per square foot evaporation a half-inch plate has a temperature of 150° C., and at 70 pounds a temperature of 170° C.

It may suffice for us to take Mr. Stromeyer's estimate that in transmitting enough heat through boiler plates to evaporate 20 pounds of water per square foot of surface per hour Miss Bryant shows that the temperature gradient in the plate will be 40° F. per inch of the thickness, and that if 140 evaporative units of heat per hour be transmitted, the mean temperature of a clean furnace plate one inch thick will be 70° F. higher than that of the water. These figures are most eloquent, and show that even with such thicknesses of plate the rise in temperature of the metal is quite a negligible quantity even at such rates of evaporation. When we deal with the much smaller thicknesses used in water-tube boiler construction it is apparent that the power of the metal to transmit heat is practically unlimited.

Of experiments conducted with actual boilers there were several qualitative trials, made in the early part of the last century, which had a certain interest; but the two prominent quantitative experiments which the writer wishes to call to notice are those made with a locomotive boiler on the Great Northern Railway of France, and with a water-tube boiler of Messrs. Niclausse, of Paris.

In the former a goods engine boiler was separated into five sections by the insertion of tube plates, the fire-box and a few inches of the tubes forming the first section, whilst the other four were composed of equal lengths of the remainder of the barrel of the boiler. Although the sections were made steam-tight, they were not insulated as to conduction of heat from one to the other, and under these conditions the evaporation from each section was measured first with all the tubes open, and second with half of them plugged up.

The quantity of water evaporated per

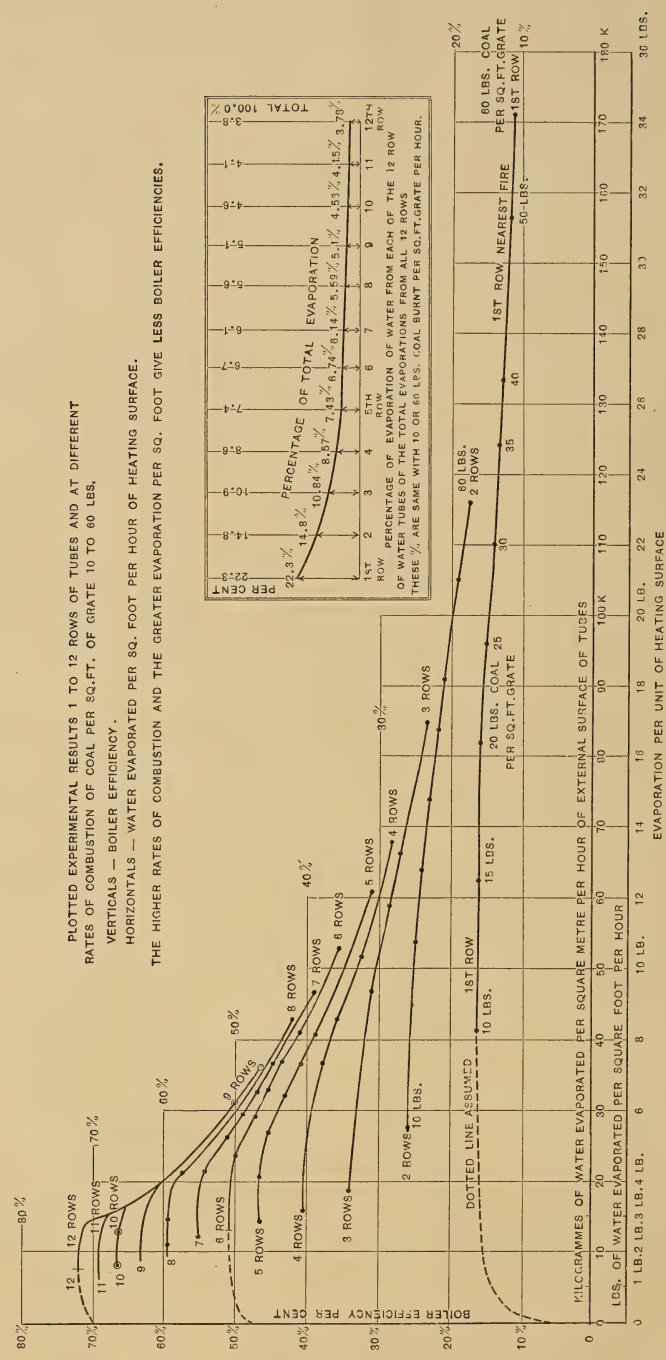

PLOTTED EXPERIMENTAL RESULTS 1 TO 12 ROWS OF TUBES AND AT DIFFERENT RATES OF COMBUSTION OF COAL PER SQ.FT. OF GRATE 10 TO 60 LBS.
VERTICALS — BOILER EFFICIENCY.
HORIZONTALS — WATER EVAPORATED PER SQ. FOOT PER HOUR OF HEATING SURFACE.
THE HIGHER RATES OF COMBUSTION AND THE GREATER EVAPORATION PER SQ. FOOT GIVE LESS BOILER EFFICIENCIES.
PERCENTAGE OF TOTAL EVAPORATION
PER CENT
TOTAL 100.0 %
PERCENTAGE OF EVAPORATION OF WATER FROM EACH OF THE 12 ROW OF WATER TUBES OF THE TOTAL EVAPORATIONS FROM ALL 12 ROWS
THESE % ARE SAME WITH 10 OR 60 LBS. COAL BURNT PER SQ.FT.GRATE PER HOUR.
1ST ROW
5TH ROW
12TH ROW
22.3 %
14.8 %
10.84 %
8.57 %
7.43 %
6.74 %
6.14 %
5.59 %
5.1 %
4.53 %
4.15 %
3.78 %
BOILER EFFICIENCY PER CENT
80 %
70 %
60 %
50 %
40 %
30 %
20 %
10 %
0
12 ROWS
11 ROWS
10 ROWS
9 ROWS
8 ROWS
7 ROWS
6 ROWS
5 ROWS
4 ROWS
3 ROWS
2 ROWS
DOTTED LINE ASSUMED
1ST ROW
10 LBS.
15 LBS.
20 LBS. COAL 25 PER SQ.FT.GRATE
30 LBS.
40 LBS.
50 LBS.
60 LBS. 2 ROWS
1ST ROW NEAREST FIRE
60 LBS. COAL PER SQ.FT.GRATE
1ST ROW
KILOGRAMMES OF WATER EVAPORATED PER SQUARE METRE PER HOUR OF EXTERNAL SURFACE OF TUBES
LBS. OF WATER EVAPORATED PER SQUARE FOOT PER HOUR
1 LB. 2 LB. 3 LB. 4 LB. 6 8 10 LB. 12 14 16 18 20 LB. 22 24 26 28 30 32 34 36 LBS.
EVAPORATION PER UNIT OF HEATING SURFACE

FIG. 4.—RESULTS OF EVAPORATION TESTS WITH A NICLAUSSE WATER-TUBE BOILER

square foot of heating surface per hour varied according to the force of draught (produced by a steam jet in the chimney supplied with steam from another boiler), in the first section from 20 to 42.9 pounds, with tubes all open and from 26.5 to 44.7 with half the tubes closed; the second section showed 5.6 to 14 and 9 to 21 pounds under the same conditions; the third, 2.9 to 6.8 and 4 to 10.6; the fourth, 1.28 to 4.32 and 2 to 6.34; and the fifth, 0.72 to 2.81 and 1.31 to 4.76 pounds. These results convey several lessons, but the writer here merely makes use of the fact that they show an evaporation of from 20 to nearly 50 pounds per square foot of surface, obtained without danger or difficulty in a portion of a by no means particularly strong form of boiler.

In the other case a water-tube boiler of Messrs. Niclausse's design was used, and each horizontal row of ten tubes was provided with upcast and downcast passages for steam and water distinct from the other rows. There were twelve rows in all, and evaporation was tested at nine different rates of combustion of coal from 10 to 60 pounds per square foot of grate area per hour. The results are graphically represented in Fig. 4, the smaller diagram showing the evaporation from each row in percentage of the total evaporation from the twelve rows, which percentage was constant for all rates of combustion tried. The larger diagram gives the plotted results on a base line of pounds of water evaporated per square foot of heating surface per hour, whilst the heat efficiencies of the boiler are shown on a vertical scale. An evaporation of from 8¼ to 34⅛ pounds per square foot per hour was obtained with the first row commencing next the fire, whilst the twelfth or topmost row evaporated only from 1½ pounds to 6 pounds per square foot per hour. The first three rows nearest the fire, with 161 square feet of heating surface, gave 47.94 per cent. of the total evaporation from 645 square feet, the remaining 52.06 per cent. requiring three times the amount of surface to complete it. Here, again, we have rates of evaporation up to 34 pounds per square foot per hour without injury to the boiler.

Both of these investigations show that it is possible to have the surface used for generating steam too much extended in a boiler, and that a large proportion of that surface in boilers as now arranged would do better duty if used for heating the water up to the point at which the formation of steam takes place in the efficient part of the generating surface. The analogy of the amount of heat required by water in heating up to the point of steam formation compared with what is required afterwards points to a larger proportion of heating surface and to a smaller proportion of generating surface.

There is one more set of experiments on evaporation to which the writer wishes to refer. These experiments were carried out by Professor Aimé Witz, of Paris, in a small vertical cylindrical boiler, about 12 inches in diameter, with a flat bottom plate half an inch thick. The water level was maintained at a constant height of 3.15 inches, the quantity evaporated being measured (of course, by the amount of feed), but the temperature of the plate was not observed.

Table III. gives the results with various sources of heating. In the last two experiments the plate was made red-hot and then the water was admitted and maintained at the same level as before. In none of the first five experiments did

TABLE III

Nature of Heating	Barometric Pressure Inches of Mercury	Temp. of Feed Water, Fahrenheit Degrees	Lbs. Water Evaporated per Sq. Ft. of Heat'g Surf. per Hr.
Seven Bunsen burners	29 33	59	13.0
Seven Bunsen burners and one air blast	29.84	61	28.8
One oxy-hydrogen blow pipe	29.84	65	41.2
Seven Bunsen burners and three blow pipes	29.65	67	54.0
Coke with air blast	29.92	67	88.9
Seven Bunsen burners, one air blast and one oxy-hydrogen blow pipe	29.70	57	136
Coke with air blast	29 92	194	204

the plate become red-hot, but the surface of the plate on the water side was kept quite clean.

Professor Witz's investigation was specially directed to the question of

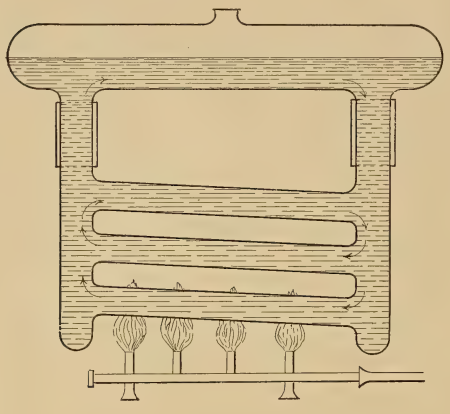


FIG. 5

whether the spheroidal state of water was likely to be produced in boilers, and although his conclusion was that it was not likely, still the conditions under which the evaporation in the last two experiments was obtained were impracticable in a boiler worked under pressure.

This introduces us to the consideration of some phenomena which constitute limiting conditions under which boilers can be worked. It has been known for some years that the tenacity and ductility of iron and steel are liable to variation with increase of temperature. This action has been made the subject of careful investigation by several workers, from Sir William Fairbairn onwards, the latest results for wrought iron and steel being due to Dr. Kollmann, Professor Martens, and Professor Carpenter. All of these show rapid loss of strength at high temperatures.

In connection with this point Mr. Stromeyer's estimate of the time required to overheat a boiler plate is of interest. Assuming that water is prevented from coming in contact with the plate, and that only steam is present on one side and fire on the other, Mr. Stromeyer says:—

"The rate at which the plate temperature rises, at least at first, can be roughly estimated on the assumption that it receives heat from the fire, but loses hardly any to the steam. The specific heat of iron being 0.11, an evaporative unit of heat (= 966 B. T. U.) entering an iron plate one foot square and one inch thick (weight 40 pounds) would raise its temperature by 220° F. We know that at a temperature of about 600° F. the elastic limit of mild steel is reduced to about one-half of what it is when cold, while at about 1200° F. the elastic limit is reduced to about one-eighth.

"If we consider a furnace plate half an inch thick exposed to a moderate heat, such as will evaporate 20 pounds of water per square foot per hour, then if the water level be lowered so as to expose the plate, its strength will be reduced one-half in the same time that one and three-eighths evaporative units would have been transmitted. The time required to do this would be eight and one-half minutes. Therefore, after exposing a plate to such heat conditions for eight and one-quarter minutes, bulging might be expected at any time, and in seventeen minutes such a furnace plate would retain only one-eighth of its original strength, and would most certainly have given way unless the original factor of safety for compression were greater than 8. If, as in water-tubes, the metal is only ⅛ inch thick, such temperatures as 600° F. and 1200° F. will be attained, respectively, in one-quarter of the periods just mentioned, or, say, in two to four minutes; but as

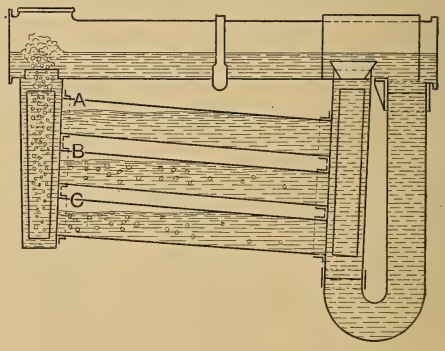


FIG. 6

such tubes have a factor of safety of from 30 to 40, one need not expect bulging before two minutes have elapsed, and even after four minutes rupture need not necessarily take place. The fact that bulges are not infrequent shows that such tubes have to stand much more than is generally believed."

Dealing with the part played by incrustation or lime "scale" in producing bulging, Mr. Stromeyer referred to the theory here as being that the lime scale prevents access of water to the plate surface, but allows a film of steam between plate and scale which permits almost any amount of overheating to take place. The conductivity of ordinary lime deposits is, however, much greater than that of a layer of grease.

"Roughly speaking," Mr. Stromeyer remarks, "scale of 1-10 inch thickness offers as much resistance to the passage of heat as does a film of grease 1-100 inch thick, or a plate of steel 10 inches thick," so that it is of great importance to exclude oily matter from the interior of boilers.

There are several other interesting subjects intimately connected with the science of steam generation, the consideration of which space restrictions here forbid. Such subjects are the effects of high pressure on the temperature of boiling and on the various chemical actions concerned in boiler incrustation and corrosion; the action of air in boilers and the means of its entrance; methods of cooling the waste combustion gases, and the comparative efficiency of feed-heaters and air-heaters.

The writer passes over these to notice a practical point connected with the action taking place in boilers as at present arranged. In almost every case the heat is applied to boilers at a low point in the structure, whether the form embrace horizontal or vertical water-tubes. The effect of this is illustrated in Figs. 5 to 8. Fig. 5 illustrates an experiment by Mr. Charles Bellens to show that with very slight inclination from the horizontal, and freedom to move in either direction, the currents of water produced were somewhat mixed. When their direction was controlled as in Fig. 6, and as it is in most horizontal-tube boilers, the steam is rapidly collected at the top surfaces of the tubes, as shown at *A*, *B*, and *C*, and also in Fig. 7, steam or a mixture of steam and froth filling a good space at the top of the tubes and in the upcast passages. This leads to unequal heating and to consequent stresses on tubes and joints. It

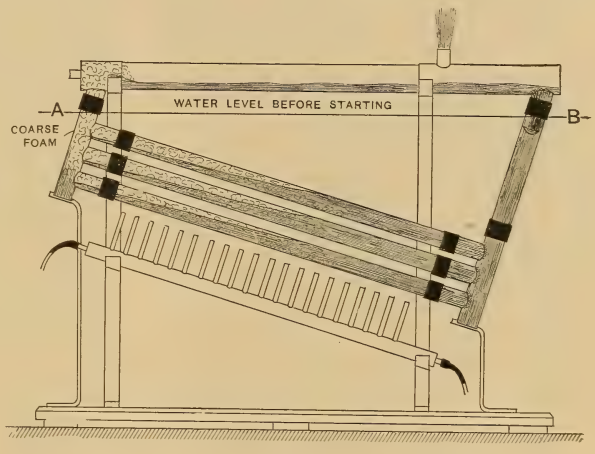


FIG. 7

will be noticed also that a considerable quantity of water is forced up above the normal water level and has to return by downcomer passages.

This result is also plainly witnessed in vertical-tube boilers, in which the greatest heat is applied at the lower ends of the tubes, as in Fig. 8, and from the point of view of heat transmission the writer believes we should look upon this action as a defective one. A good deal of the water so thrown up cannot have the temperature of the steam, but can borrow heat from the steam, and, moreover, must lose heat probably by radiation in the operation of returning by downcomer passages which must not be exposed to the full heat of the fire. We have very little appreciation, until

the question is raised, of the magnitude of the action which this involves.

Mr. W. H. Booth has made a calculation founded upon a given rate of evaporation, and, therefore, of cubic space occupied by steam as found at a given pressure in water tubes and of its necessary speed of movement. For boilers of the small-tube variety, with tubes about 1½ inches in diameter, 5 feet long, with 20 square feet of grate surface and a ratio of tube to grate surface of 45 to 1, there might be 600 times the amount of the boiler feed circulating in the useless way described. Mr. Thornycroft claimed to have measured 100 times the feed in one of his boiler models, and Professor Watkinson claimed 240 times the feed from his calculations based on the action of glass models, and any of these figures represents a very large quantity of water in a boiler even of moderate dimensions.

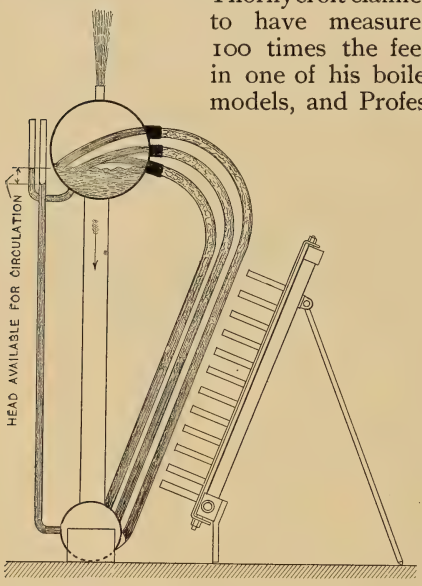


FIG. 8

For instance, in Mr. Booth's example, with 450 tubes evaporating 1170 gallons per hour, if 600 times the feed were the quantity passing by the downcomers per hour, that would mean 700,000 gallons in that time. This is probably an extreme case, but the writer refers to it in order to direct attention to what strikes him as a defect in the present system of applying heat to water tubes. Means for eliminating it will most certainly be devised as time goes on.

Before concluding this rapid survey there are some considerations affecting the form of a boiler which claim notice. The action of pressure in altering the forms of some boilers has long been known in certain of its effects. In cylindrical boilers this evidence has been obtained from the effect called "grooving," principally in the neighbourhood of lap and butt joints; but, of course, the necessity for having stays to support flat surfaces is a distinct testimony to the same action,—that is to say, it is an attempt to prevent it. The reason of it is found in the law of fluid pressures which is known as Pascal's law. Apart from the action of gravity, this law states the fact that pressure exerted upon a mass of liquid is transmitted undiminished in all directions, and acts with the same force on all equal surfaces and in a direction at right angles to these surfaces. The tending of such an action is, therefore, to cause any vessel which is subjected to internal pressure to assume the form of a sphere, and where there are irregularities of form, or greater departures from the spherical in some portions than in others, greater strain will be thrown upon such portions or their immediate connections.

Some interesting measurements of such deformations under the influence of pressure in cylindrical or Scotch marine boilers were given by Mr. J. T. Milton in a paper before the Institution of Naval Architects in 1893. The fact, too, that the load borne by any vessels, or portion of a vessel, is proportional to the area, gives the reason why with boilers of the cylindrical or drum type the weight of material has to be very greatly increased with increase of pressure, and shows us that we can have lighter scantlings of material and yet far greater strength in boilers properly designed with small areas, such as some of the water-tube class.

There are, in addition to these pressure stresses, strains set up by the action of the heat, which must be provided for. These temperature stresses amount,

in the case of good wrought iron or steel, to from 186 to 190 pounds per square inch of section per degree Fahrenheit increase of temperature, and in the case of cast iron to about 100 pounds per square inch. Expressed in another way, we may reckon what the stress is by taking a bar of wrought iron one inch square in section and finding that the elongation or stretching of that bar, when cold, by the dead pull of one ton weight, will be exactly reproduced by heating the bar 16.8° F. The effects of a force of 12 tons would, therefore, be produced by heating the metal 200°, and of nearly 24 tons if it were heated through 400°. We cannot wonder that under the action of such a force, when due provision has not been made for it, cylindrical boilers have been torn through the solid shell plating, or that tube plates have become deformed and tubes have been crushed out of proper contact with them at their joints, or that the tubes of some water-tube boilers have become bent and leaky.

Mr. A. F. Yarrow made use of the apparatus shown in Fig. 9 to demonstrate the expansion of the vertical stays nearest the tube-plate in a locomotive type marine boiler, and stated that the movement was often sufficient to enable a penny to be inserted between the nut on the stay and the gland of the stuffing-box. Mr. Yarrow also used bars fitted through tubes at different levels in the boiler, as is shown diagrammatically in Fig. 10, to register the bending of the tubes through unequal expansion. As both ends of the tubes were held rigidly in tube-plates, any expansion in individual tubes must produce either bending of the tube or distortion of the tube-plates. Probably both happened, but the rods in Fig. 10 very plainly indicated the course of the heating. The top tubes commenced to bend first, then, after an interval, the second bar, and, later, the lowest bar moved. When steam pressure was got up, the pressure, forcing the tube plates asunder, straightened the tubes.

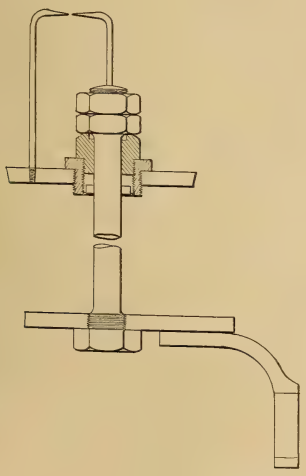


FIG. 9

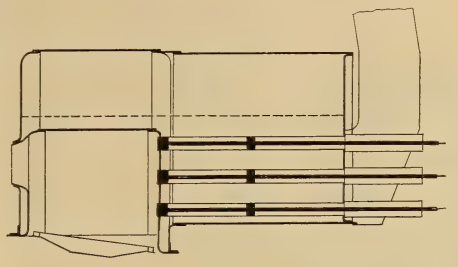


FIG. 10

Although these experiments were carried out with fire-tubes, they convey lessons which are applicable also to water tubes, and show that a properly designed boiler must possess ample provision for the action of natural forces which come into play during its working. That provision is not made in many boilers, and its absence leads to frequent repairs.

The intermittent character of many of these strains, whether produced by direct pressure or due to the action of heat, rather intensifies their bad effects.

It will thus be seen that we have a many-sided problem before us in designing or even in considering a steam generator, and although the writer cannot but feel that he has given a very inadequate account of the subject, he hopes that he has at least indicated the vast field of possible improvement which awaits all the skill and energy which can be brought to bear on it.

POWER FOR LARGE MACHINE TOOLS

By Charles H. Benjamin

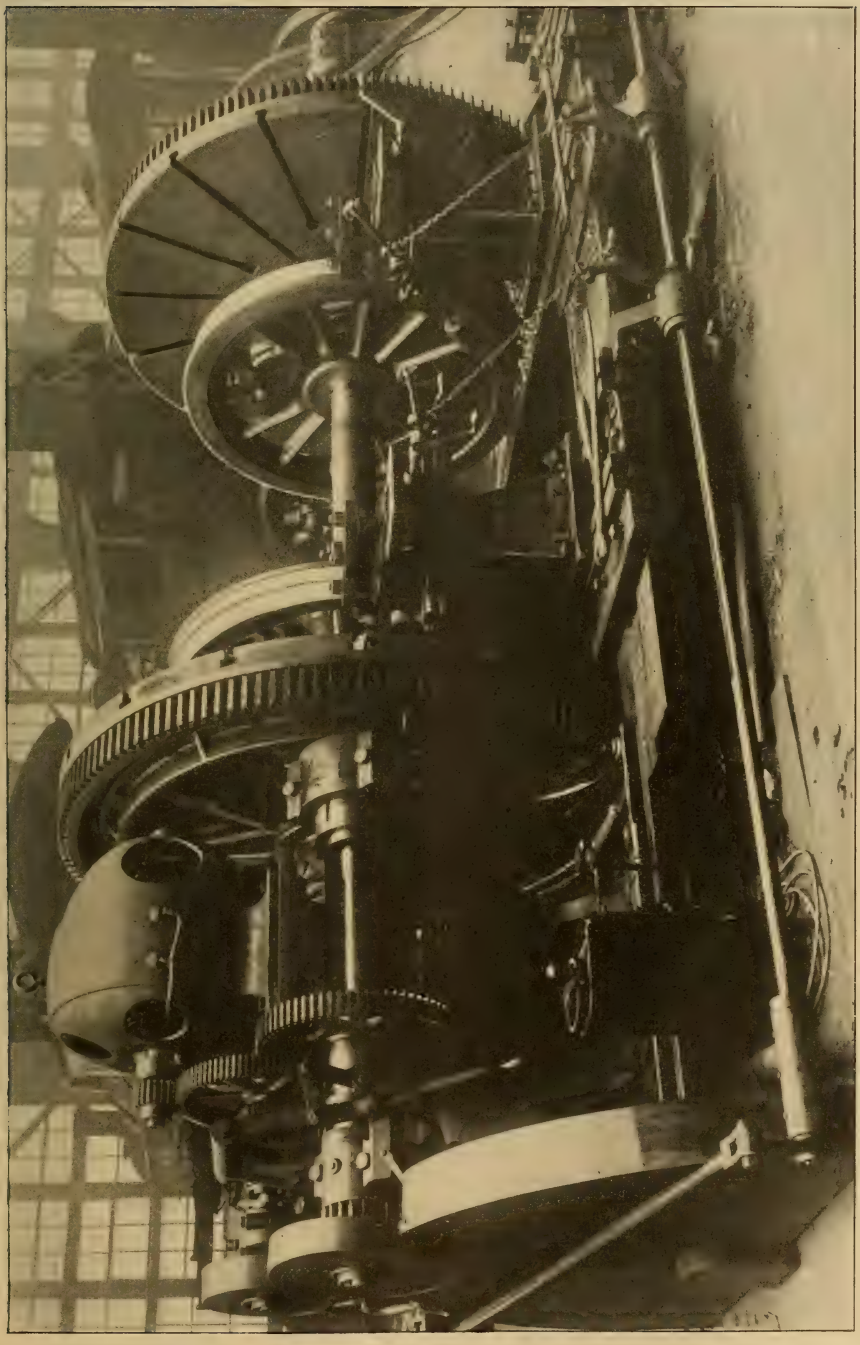
THE introduction of large units and the more general use of air-hardened steel have made it necessary to revise our estimates of the power required to drive modern iron-working machinery. Experiments made eight or ten years ago on lathes and planers then in use showed one or two horse-power per machine to be a large estimate. To-day machine tools are larger and stronger, and they are worked to the limit of endurance of tool and of machine.

Fortunately, the more general use of electric transmission makes it possible to determine the amount of power actually absorbed by the machine itself and by the work with a reasonable degree of accuracy. Machines which are driven directly by a single electric motor are especially well adapted to such a line of investigation. During the winter and spring of 1902-1903 six senior students of the Case School of Applied Science made a comprehensive series of measurements on electrically-driven machines in two large modern establishments. These experiments were conducted under the direction of the writer, but the students are entitled to all the credit for carrying out the details of the work. The tests at the works of the Wellman-Seaver-Morgan Company, of Cleveland, Ohio, were made by Messrs. Courtney, Hanlon, and Hoffman, and those at the Collinwood shops of the Lake Shore & Michigan Southern Railway by Messrs. Anthony, Seaton, and Sullivan. Acknowledgments are due the proprietors and managers of the two establishments for the courtesy which made such experiments possible.

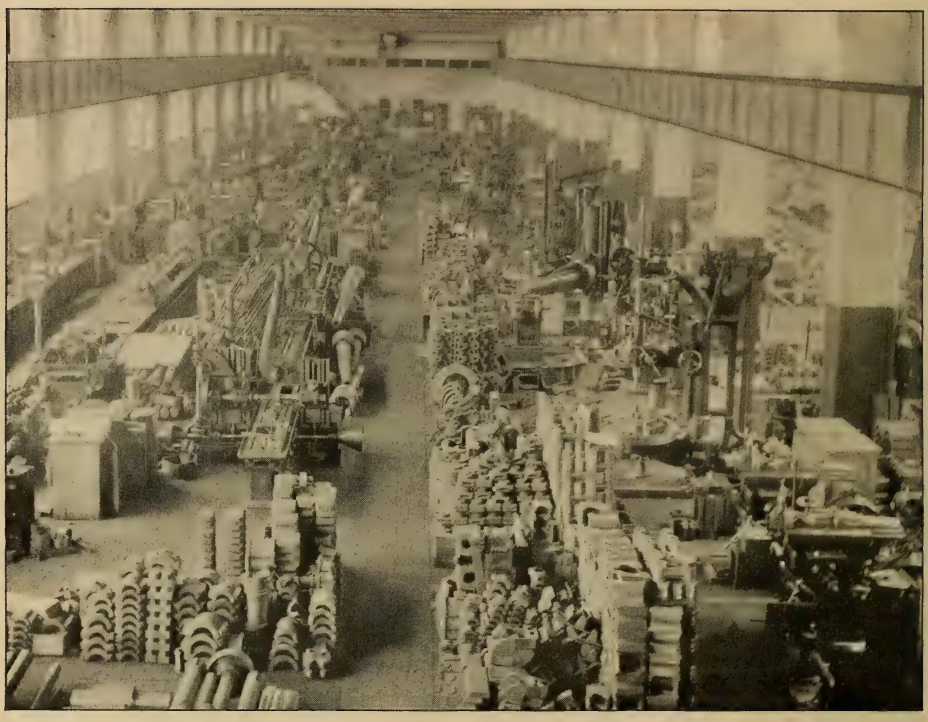
The shops of the Wellman-Seaver-Morgan Company are driven wholly by electric motors, no belts being used, and each machine being driven by a separate motor. The Westinghouse three-wire system is employed, with voltages on the wires of 110 and 220 volts. On all rotary machines variable-speed motors are used, giving variations of from one to four or one to five. Further variations are obtained by the usual mechanical means. On the planers constant-speed motors are employed, and speed changes are effected by gearing and reversals by the Wellman-Seaver magnetic clutch.

It is to be noted that all figures for horse-power include the losses in motor and in controller. It is not necessary in this article to go into the details of the electrical measurements; suffice it to say that the currents and voltages in the several tests were measured by standard instruments which had been carefully calibrated.

The number and kind of tools used were noted, the cutting speed and the depth of cut, and the quantity and kind of material removed in a given time were also recorded. On one Sunday during the time of the experiments friction readings were taken from the various machines, by lifting the tools from the work and running the machines as before at different speeds. Observations were also made on the power required to start and to reverse some of the machines. The machines tested in this shop consisted of five boring mills, varying from 3 feet to 10 feet capacity; two lathes of 48 inches and 60 inches swing, and two planing machines, respectively of 37 inches and 48 inches capacity.



AN 84-INCH DRIVING WHEEL LATHE IN THE SHOPS OF THE LAKE SHORE & MICHIGAN SOUTHERN RAILWAY. MADE BY THE NILES TOOL WORKS CO., HAMILTON, OHIO, U. S. A.



A SHOP WITHOUT BELTS. THE WELLMAN-SEAVER-MORGAN COMPANY, CLEVELAND, OHIO, U. S. A.

A brief description of a test on a 3-foot boring mill will illustrate the methods used. This machine was driven by a five horse-power motor capable of running at four different speeds, from 300 to 1200 revolutions per minute. The work consisted of a cast steel gear blank 22½ inches in diameter and 5 inches face. The accompanying table shows the principal results obtained:—

Cutting Metal			Running		Idle
Controller Notch	Time Mins.	Horse Power	Horse Power	Revs. Motor	per Min. Table
5	33	3.00	1.36	464	4
6	52	3.21	1.31	--	--
7	5	2.16	1.31	--	--
9	10	2.12	1.57	--	--

Total duration of test, 100 minutes.

Total weight of metal removed	31 pounds.
Metal removed per net H. P. per hour (average)	17.8 "
Net horse power per cubic inch of metal removed per minute	0.96
Net horse power per pound of metal per hour	0.056

The new shops of the Lake Shore & Michigan Southern Railway at Collinwood, Ohio, also are electrically driven, but in a different manner from the establishment just described. The Crocker-Wheeler four-wire, multiple-voltage system is employed. By various combinations six different armature voltages are obtained on each motor, giving six different speeds. By the use of a controller and the introduction of resistance other speeds could be obtained, making in all twelve forward and seven reversing. By the further use of gears in some of the machines still other changes are effected, giving sometimes as many as seventy-two speeds on one machine.

A mixed system of transmission is used, the larger machines being driven by individual motors varying from three to twenty horse-power in capacity, while the smaller tools are arranged in groups and are driven by constant-speed motors of from seven to twenty-five horse-power. Most of the individual motors have the multiple-voltage control, but a few of these are of constant speed, and mechanical speed control is used.

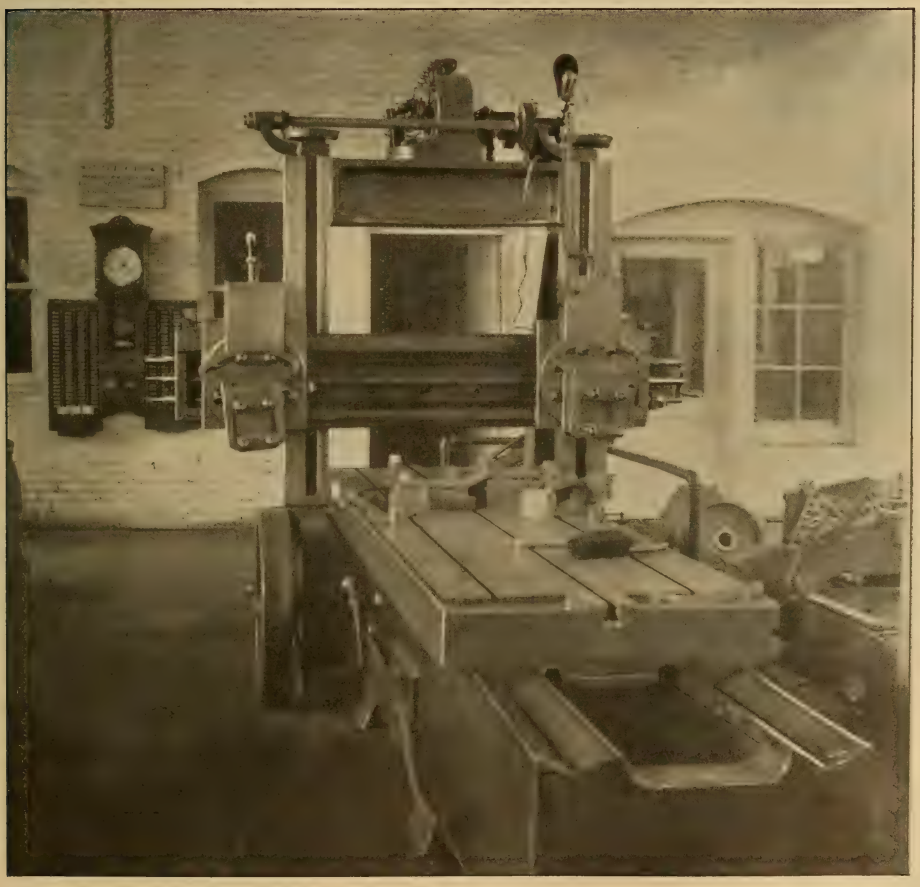
All the tests made in these shops were

RESULT OF TESTS MADE WITH A 36-INCH LATHE

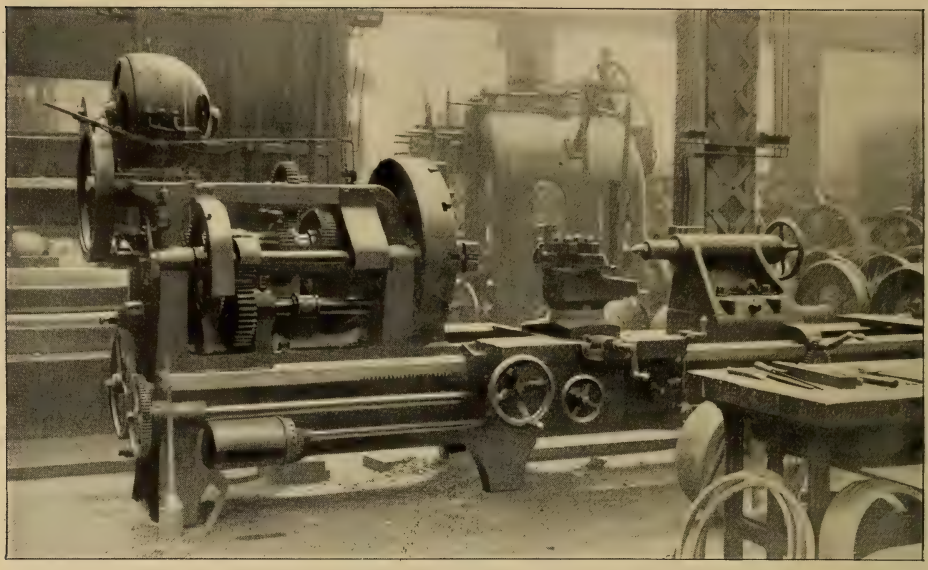
Revs. per Min	Cutting Speed Feet per Min.	Horse-Power Total	Horse-Power Friction	Horse-Power Net	Metal Removed Cu. Ins. per Min.	Metal Removed Lbs. per Min.	H. P. Consumed Per Cu. In. per Min.	H. P. Consumed Per Lb. per Min.	Cut
3.28	16.8	0.937	0.562	0.475	0.87	0.220	0.545	2.1	
3.75	19.2	1.127	0.562	0.565	----	---	----	----	Face
3.75	20.8	1 45	0.562	0.888	----	----	----	----	Rough'g
3.75	20.2	1.57	0.562	1.01	2.06	0.536	0.485	1.88	
4.00	21.2	1.44	0.562	0.88	2.37	0.616	0.371	1.43	
4.00	20.4	1.59	0.562	1.03	1.16	0.301	0.89	3.44	Face
4.00	20.8	0.882	0.562	0.32	2.12	0.551	0.151	0.582	

upon lathes equipped with individual motors and doing the regular routine work of the shop. The time of the run, the speed of the machine, the depth of cut, and the amount of material removed were all recorded. The voltage and current in both field and armature were determined at short intervals. At such times as were available, readings were taken with the machines running idle, to determine the friction loads.

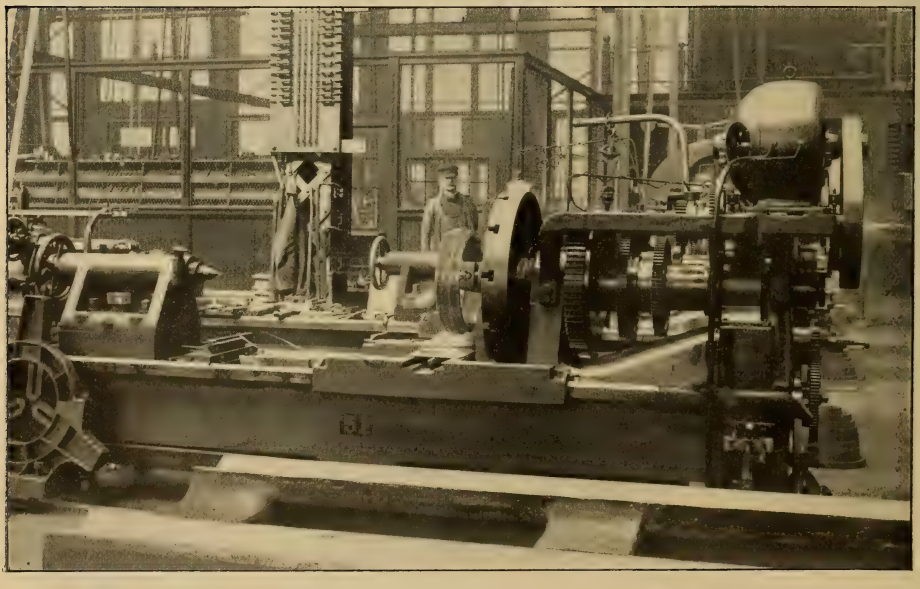
As an example, we will take a 36-inch, triple geared engine lathe, built by the Pond Machine Tool Company. This lathe is driven by a motor having a capacity of 7½ horse-power at 675 revolutions per minute. Friction tests were made at the twelve different notches of the controller and at six different combinations of gears, giving in all seventy-two different combinations. The friction horse-power varied



A 48-INCH PLANER MADE BY THE POND MACHINE TOOL CO., PLAINFIELD, N. J., U. S. A., IN THE WELLMAN-SEAVER-MORGAN COMPANY'S SHOP



A 36-INCH TRIPLE-GEARED LATHE IN THE LAKE SHORE & MICHIGAN SOUTHERN RAILWAY SHOPS. MADE BY THE POND MACHINE TOOL CO., PLAINFIELD, N. J., U. S. A.



A 30-INCH POND LATHE IN THE SAME SHOPS

CHIPS FROM THE LAKE SHORE SHOPS

from 0.288 at the lowest speed and first notch of the controller to 2.72 at the highest speed and last notch of the controller. The changes in gearing had but little effect on the power consumed.

The lathe was then tested while machining a cast-iron ring about 20 inches in diameter. Seven different cuts were taken in roughing and finishing the piece, with the results given in the table at the top of page 149.

It is to be noted that the last two columns of horse-power are based on the net horse-power.

Another good example is an 84-inch driving-wheel lathe, made by the Niles Tool Works, and equipped with a motor of 15 horse-power capacity at 800 revolutions per minute. Friction readings were taken of this machine at the twelve different controller notches, showing a horse-power varying from 0.556 at notch No. 1 to 2.58 at notch No. 12.

Readings were next taken while machining a pair of steel-tired driving wheels about 54 inches in diameter. It was found that the mere weight of the driving wheels increased the friction of the machine about 10 per cent. Four different cuts were taken,—roughing, cutting bevel, smoothing corners, and finishing. The depth of cut varied greatly during the test, with a consequent variation in the power required. The total horse-power varied from 1.7 to 5.24 and the net horse-power from 0.05 to 3.58, the average being 3.02 total and 1.37 net horse-power. The cutting speed was 7.64 feet per minute, self-hardening steel being used in the tools.

The total time of the run was two hours and thirty-five minutes, and the total weight of metal removed was 66 pounds. This gives 1.5 cubic inches or 0.426 pounds of metal removed per minute and a consumption of power of

SUMMARY OF TESTS IN THE SHOPS OF THE WELLMAN-SEAVER-MORGAN COMPANY

Machine	Horse-Power of Motor	Duration of Run, Min.	Material Cut	Horse-Power Total	Horse-Power Net	Metal Removed Total Pounds	Metal Removed Per Hour Pounds	Horse-Power (Net) Per Cu. In. per Minute	Horse-Power (Net) Per P'nd per Hour
10 ft. Boring Mill	10	90	Cast Steel	2.88	1.12	----	----	---	---
8 ft. "	10	105	Cast Iron	4.04	1.82	37	21.1	1.47	0.086
5 ft. "	7.5	220	Cast Steel	2.74	1.80	47	12.8	2.40	0 141
4 ft. "	7.5	140	Cast Steel	2.60	1.57	45.5	19.5	1.41	0.081
3 ft. "	5	100	Cast Steel	2.99	1.05	31	18.6	0.96	0 056
60 in. Lathe	10	60	Cast Steel	10.59	8.25	117.5	117.5	1.19	0.070
48 in. "	7.5	24	Cast Iron	1.79	0.86	7.66	19.1	0.86	0.045
14′ x 48″ Planer	20	63.5	Cast Steel	5.51	1.12	15	14.2	1.34	0.079
13′ x 36″ "	15	80	Cast Steel	4.31	0.18	10	7.5	0.41	0.024

NOTE.—The 48 in. planer consumed 7.16 H. P. in starting and 11.4 H. P. in reversing. The corresponding figures for the 36 in. planer were 4.4 H. P. and 6.96 H. P.

SUMMARY OF TESTS IN THE SHOPS OF THE LAKE SHORE & MICHIGAN SOUTHERN RAILWAY

Machine	Duration of Run, Mins.	Material Cut	Horse-Power Total	Horse-Power Net	Metal Removed Total Pounds	Metal Removed Per Hour Pounds	Horse-Power (Net) Per Cu. In. per Min.	Horse-Power (Net) Per Lb. per Hour
	12.6	Steel	2.57	1.29	8.53	40.6	0.466	0.032
42 in. x 18 ft. triple-geared engine lathe, turning steel axle, motor 10 H. P., at 850 rev. per min.	5	"	4.09	2.78	5.3	63.4	0.686	0.044
	2.8	"	----	----	0.73	15.6	----	----
	11.75	"	2.62	----	8.30	42.4	----	----
	33.5	"	8.55	----	28.9	51.8	----	----
	11.	"	1.34	----	0.79	4.3	----	----
	14.	"	0.89	----	0.795	3.4	----	----
42 in. x 16 ft. triple- geared engine lathe, 10 H. P. motor	14.5	Cast Iron	1.65	----	0.80	3.33	----	----
	12.5	"	1.64	----	0.60	2.89	----	----
	34.5	"	1.69	----	3.28	5.70	----	----
42 in. car-wheel lathe, 20 H. P. motor	14.1	Steel	5.35	3.54	126	53.6	1.11	0.066
84 in. driving-wheel lathe, motor 15 H. P., at 800 rev. per min.	120.5	Steel	5.33	3.92	218.7	109	0.61	0.036
	155	"	3.02	1.366	66.	25.5	0.907	0.053
	22	Cast Iron	0.937	0.475	4.98	13.6	0.545	0.035
36 in. triple-geared engine lathe, motor 7.5 H. P., at 675 rev. per min.	7	"	1.57	1.01	3.75	32.2	0.485	0.031
	5.75	"	1.44	0.88	3.55	37.	0.371	0.024
	3.5	"	1.60	1.04	1.05	18.	0.890	0.057
	3.42	"	0.88	0.32	1.88	33.1	0.151	0.010
	22	Cast Iron	0.74	0.21	0.48	1.31	2.45	0.160*
28 in.—48 in. extension gap lathe, motor 7.5 H. P., at 875 rev. per min.	22	"	0.70	0.17	0.51	1.4	1.88	0.121*
	24	"	0.75	0.22	1.8	4.51	0.746	0.048
	8	"	1.17	0.63	1.37	10.32	0.957	0.061
	6.5	"	1.31	0.77	1.38	12.72	0.947	0.061
	3.	"	0.77	0.23	0.30	6.06	0.588	0.038

* Inside cut.

0.907 horse-power per cubic inch per minute, or 3.2 horse-power per pound per minute. Other tests of this same lathe are shown in the summary. Self-hardening steel was used for tools on all the lathes tested. The tables given on this pages are summaries giving the principal data and results in both shops. Several facts will be noted.

First, the small amount of power in average daily use compared with the total capacity of the motor and machine.

Second, the relatively large value of the frictional horse-power on account of the first-mentioned fact, usually from one-half to two-thirds the total power used.

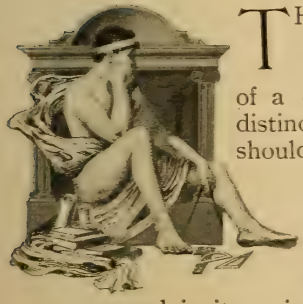
Third, a great variation in the net horse-power per pound of metal removed per hour, the values running from 0.024 to 0.160. The latter high value was obtained with an inside or boring tool, which perhaps accounts for the poor efficiency.

SOME ASPECTS OF THE LABOUR PROBLEM

BUSINESS PRINCIPLES IN THE CONDUCT OF INDUSTRIES

By Dr. Robert H. Thurston

Dr. Thurston's sudden death a few weeks ago has left a gap, not soon to be closed, in a large circle of friends and admirers. His cheer of manner, his hearty good fellowship, and his splendid accomplishments in the front rank of engineers and educators all united to produce an impress of an enduring kind. Probably the last thing from his pen, written for publication, was the paper printed in the following pages.—THE EDITOR.



THE business principles involved in the conduct of the industries of a country include two distinct codes; one of these should control the whole system of the nation; the other should guide the conduct of its details as affecting the individuals engaged in its various industries. These two codes are not entirely independent, and are not at all conflicting in their requirements. Both are simple and self-evident in their formulas, and both are founded upon obvious and unquestionable principles. Both have their economic, their moral and their legal aspects, and, combined, they constitute the proper and only proper system of principles which should control all industrial operations.

The national code should consist of the following fundamental laws:—

1.—The nation should make itself industrially, as well as politically, independent.

2.—The national system of industries should be so adjusted and administered as to insure the production within its own borders, just as completely as may be practicable, the natural resources permitting, of all the essential industrial products of a civilised community.

3.—Every natural resource should be developed as completely as possible and as efficiently as practicable.

4.—The system of national industries should be made capable of employing every citizen in the field of work in which his talents make him most useful, and as continuously as is possible at his best rate of economical production. The population, as a whole, should be thus made in maximum degree contributive to the welfare of the world. The industrial system, considered as a machine, should be made thus in maximum degree economically efficient.

5.—The political and the legal and the moral rights of every citizen should be maintained, and the best interests of the nation thus made to conspire with

A RECENT PORTRAIT OF DR. THURSTON

the highest interests and the individual rights of its citizens.

6.—The fundamental principle to be at all times recognised and insured is that of maintenance of the law and preservation of the peace under the law, at all times and in all places and at all costs, even of life, if need be, by the constituted authorities.

The code for the citizen should include the following:—

1.—The right of every citizen to freedom, entire independence in right-doing, and perfect liberty in the pursuit of happiness, financial competence, and a higher knowledge, to found a home and to educate children and to provide them with opportunity for similar success in life should not only not be denied or infringed, but should be made a first consideration and emphatically assured.

2.—Every individual should be assured of entire liberty to acquire education, property and the respect of his fellows, and of safety and permanence of all that he may gain by his own wisdom, experience, skill, industry, and frugality.

3.—The individual, of whatever race, creed, or condition, and of whichever sex, should be made absolutely free to take up any vocation, to display his talents in any legitimate industry, and to work wherever, however, for whomsoever, and on whatever terms he may find to his liking. His right to make a bargain should be made absolutely safe and inviolate.

4.—The right to individual freedom and independence should be recognised as second only to that to life itself, and the right to defend that right to the death should be a fundamental principle.

The moral right of the citizen and his duty are complementary. He should be assured of the one absolutely, and the other should be uncompromisingly exacted of him. His moral rights include perfect liberty of conscience and of judgment and entire liberty of action within the law. He should be guaranteed the right to form his own creed respecting social matters as in matters of theology and of scientific deduction. He should be permitted to work by himself or with others of like views; he should be given freedom to act for himself as an individual or to join with others in co-operation in any good works. He should be *compelled* to permit every other citizen the enjoyment of the same rights.

He has the moral right to protection of life and liberty and to achievement and possession of his own. He has the right to train his children in what seem to him the wisest courses, and to educate them as far and as well as his circumstances permit, to obtain for them opportunity to make themselves in maximum degree useful to themselves, the family, and the world. He has a moral right to seek his own success in any legitimate path and in any form which may seem to him desirable,—provided he does not infringe the individual or the collective rights of his neighbours. In any case of antagonising interests he has a right, moral, and presumably legal, to demand that the rights and wrongs of the case be precisely defined, and that he be given his individual rights irrespective of the character, the position, the social or financial standing of the other man. But these rights must be defined by properly constituted authority and not by the interested participant in any dispute.

The legal rights of the citizen are simply the formulated expression of his moral rights and of his relations to the body politic. The legal code is the summary of the conclusions which a study of good morals and of industrial ethics in the light of good sense and of good morals and good manners compels. Laws contradictory to these principles are bad laws and should be excised from the statute books.

The primary legal principle affecting the individual apart from the provisions of the criminal law is that which gives every man the right to make his own agreements and to conclude his own bargains without impediment or interference. A bargain is an agreement entered into freely by two individuals, or two parties, each finding it profitable and satisfactory to himself. No man

can be compelled to enter into an agreement in business matters or to make a bargain the result of which is not, in his view, the best that he can make and a profitable one to himself. Compulsory bargaining, like compulsory arbitration, is a contradiction of terms.

While it is physically possible for the state to formulate a code of law which may contain or involve a wrong principle or a bad practice, it is always to be assumed that reference to the constitution of the state or nation will lead the supreme legal authority to restore the code to correct form. The fundamental principle on which must rest all others, legally as well as socially and morally, is expressed in the maxim,— "The state must maintain the law and must preserve the peace."

When the law is maintained and the peace is preserved by the authorities all disputes must settle themselves without hostile meetings, and they always will be settled without endangering the individual, the state or the nation. This one maxim forces all ill-disposed or unjust citizens to submit to ultimate justice.

Strikes and boycotts are, usually, simply endeavours, by forcible means, to compel another to make a bargain satisfactory only to the attacking party. They involve the endeavour to secure a bargain by compulsion which could not be secured with mutual advantage and by common agreement as the best for both parties that could be arranged at the time and under the circumstances. They preclude the separation of the two parties to the negotiation and freedom of both to open other negotiations where a proper and rightful bargain may be made.

In either case one party determines that it should secure a better compensation for what it has to offer and then seeks to compel the other side to its own estimate of the value of its offering. When such efforts are made to secure compulsory agreement with the claims of the attacking party success can rarely be secured except by forcibly destroying all competition, and strikes are almost invariably accompanied by illegal violence and often by public disorder, not infrequently by destruction of life and property. The whole tendency is toward the production of lawlessness, lack of respect for legal authority, and general demoralisation. Where such violence and compulsory evasion of competition and a fairly complete monopoly of power are not observed the outcome is always simply that which natural industrial laws would bring about.

If labour be plentiful, and its value, therefore, reduced, a strike will fail; when the class of labour needed is scarce, and its value, therefore, is high, a strike will generally succeed. But these results are simply the ordinary and normal outcome of the ultimately controlling principle in any case. Prices rise or fall as the supply is less or greater than the momentary demand. Employment being ample for all, prices of labour rise; the call for labour falling off, wages fall. If the wages are held constant by an artificial system or by brute force, the numbers employed will be less in hard times than the normal, and more people will suffer. In good times no more than all can be employed. The net result is probably a loss to the individual and to the country.

The nature and method of compulsory interference with the rights of any individual or body of men seeking a mutually agreed-upon contract are thus antagonistic to the principles of good business. They are usually resultant in harm, and in many ways. The employees have a legal and sometimes a moral right to retire from employment, precisely as has the individual,—no more, no less. The employer has the legal and sometimes the moral right to close an establishment and go out of business either temporarily or permanently; but when the legal right is exercised by either for the purpose of exercising compulsion in the making of a bargain, the moral right is exceeded. Either party may exercise this right in self-defence or in self protection; but neither has the moral right to so act in compulsion of the other. Either side has a right to place a value on the article offered for sale, but neither has a right to compel the other to accept that

valuation. If an agreement cannot be reached, the only proper course is for the two parties to separate and seek better terms elsewhere. This often means a hardship, especially to the man without reserves; but that fact does not change the principles or the right of the question.

A peaceable strike is entirely legal, though often unwise; a forceful strike is both illegal and impolitic, as a rule, if not always. The nature and the method of the strike, as of the boycott, are contrary to good morals and good manners, even if not directly resultant in crime and infringement of the rights of neutrals.

It is sometimes claimed that a strike is war and that, like war between nations, some methods and some acts are proper and right which are not right in time of peace. A strike is sometimes likened to justifiable rebellion, but it is to be remembered that usually a large majority of the other individuals composing the nation are directly or indirectly wronged by strife, and that only the nation can declare war. The courts uphold the right to strike and to combine to strike; but no court upholds the boycott, the strike, or the monopolising of the right to labour, by the exertion of force against neutral members of society.

The economic results of strikes, boycotts and other irregular interference with the course of trade are always more or less disastrous. It rarely happens that even the side which gains the victory in such strifes secures compensation in full for its losses in war. The losing side invariably sacrifices largely by the strife. The country loses enormously through the interruption of production, and this is a loss which never can be repaired. Time and work lost are never recoverable. Such economic wastes are a tax on the whole community, and the acts which cause them are in direct conflict with the primary principles of industrial progress.

The moral results of industrial strife are even more deplorable than the purely economic consequences. The loss of time, labour, and money is serious and far reaching, and ultimately tells against the best interests of the people; not unusually it leads to sacrifice of health and of life itself. The moral results are demoralisation of whole communities, the loss of respect for law, and the promotion of disorder and crime. The subordination of the good to the bad, of the lawful and law-abiding to the lawless and law-breaking, means the degeneration of the nation and the introduction of anarchy. It is the initiation of a retrograde movement of humanity which has its limit only in barbarism.

The social effects of industrial war are simply the natural outcome of economic inefficiency and of moral retrogression, the inevitable and always to be expected outcome of the infraction of those principles, practices, and methods which have been the slow evolution of the later centuries. It is not that the classes and the masses become sharply distinguished, but that the masses submerge the best classes, and with no possible chance, as now, of the advancement of the deserving to higher positions in the community and of the skillful, wise, industrious, and frugal to independence.

When a ship is wrecked on the rocks of a dangerous coast and its crew is cast into a boisterous sea, the only safety for the many is the prompt attainment of the few of a safe position on the shore from which to reach out a helping hand to the others. In any ship of state the best chances for the people come from the exertions of the able and competent and well disposed who have secured, by their skill, energy, ambition, and general efficiency, positions of security from which they may, and must, inevitably, through the operation of natural industrial law, lend a helping hand to their fellows. Precisely as only the existence of men of learning can promote the education and the fitting of the teacher of the people, and, through them, the intelligence and knowledge needed by the people as a body, so it is only through the work of great men of business and the operations of great capitalists that the success of the people in gaining pecuniary independence can be assured in maximum amount.

The legal aspects of the case are already well settled by the later decisions

of the courts at law. The right of every man to act, individually or in co-operation with however many others, is assured by the laws of the state and by the dictates of good sense and good feeling, as well as by the law itself, up to that limit at which the individual or the association of individuals begins to infringe upon the rights of others. At that point limitation is necessary, and the enforcement of that limitation is essential to the life of the nation, as well as to the freedom and independence of the citizen.

The remedies for conditions producing economic inefficiency and industrial anarchy, for moral degeneration and social disorder, are as simple as are the conditions themselves and the causes from which they spring. These remedies may be readily applied and made thoroughly successful provided they are prescribed and enforced by wise, honest, determined, and patriotic men. The primary necessity in their application is an intelligent body politic; the next requirement is representation of the people by their best element and the construction of legislative bodies of wise, honest, determined and patriotic representatives of the people. The final necessity is power to enforce the will of the well-meaning and intelligent majority by legal and peaceful ways, when practicable, and by force if need be. The mob must be made powerless, the people all-powerful. Disorder and crime must be promptly and sternly repressed and the natural and legal rights of every member of society, however humble or weak, assured against the criminal, the selfish, and the ignorant and foolish rebel against law and order.

Educational remedies for the industrial diseases are found in the extension of the public school system throughout the whole nation and in the improvement of the system as a means of spreading throughout the whole mass of the people an intelligent apprehension of the principles bearing upon industrial questions and of the facts which are revealed by experience and by the history of our own and earlier times, illustrating the results, good and bad, of correct and of incorrect industrial methods. It is the common school system upon which we have learned to mainly rely to secure a general and liberal culture amongst the people, sufficient at least to enable the responsible citizen to understand and intelligently to vote upon the questions of the day in politics and in economics. The improvement of this system also insures a more efficient body of teachers for the next generation of children, for the teachers are mainly supplied by the common school system of education rather than by the colleges and universities. If these teachers are earnest and patriotic and intelligent and well-informed, the next generation is likely to be similarly earnest, patriotic and intelligent and well-informed. If the race of teachers is improving, the race of citizens will improve.

The improvement and extension of higher education is an important element of this progress. No stream can rise higher than its source. The loftiest source of learning, culture, and intellectual, if not of moral, progress is the university and its body of learned investigators, and the college with its great faculty of presumably wise men. These institutions are the ultimate sources of all contemporary learning and culture, wisdom, and real knowledge. With their advancement and with their progress in character, learning, and effectiveness in work goes the progress of a nation.

Legal remedies for industrial disorders are to be found in an intelligent and well-digested system of legislation which shall, first of all, insure the maintenance of the law by its official representatives and their staffs and the preservation of the peace by every needed power of the individual officer, his staff, the municipality, the state, the nation if need be. The code should, further, insure to every citizen, without regard to age, sex, colour, creed or vocation, absolute freedom of action within the range of the moral law. Freedom and independence are the rightful heritage of every individual citizen, and freedom to engage in the pursuit of any innocent form of life, liberty and happiness should be

maintained by the individual, at the risk of life, if need be, and guaranteed by the state at all hazards.

Life is worthless and governments are failures if the citizen is to be dominated by other powers than those of good laws, established and faithfully administered by the freely chosen representatives of the people.

No individual and no class can be safely permitted, for an instant, to assert its right to rule over another, much less to attempt to establish that rule. The bad legislator should be condemned as a traitor, and, as such, punished in such manner that no one will be inclined to follow his dangerous example; the bad citizen, whether acting as an individual or with a class or a club or with a party, whether an executive of the law or a private citizen, should be given the same judgment and the same treatment. The individual seeking his own personal advantage at the sacrifice of the interests of his fellows, of the city, or of the state or nation, should be legally placed in the same category and subject to the same judgment.

Social remedies for the economic and social errors of the time are to be found in the cultivation of a well-defined and well-established private and public sentiment in favour of good morals, good manners, and high culture, such that not only the individual, but the body politic shall constantly gain in these directions. When a nation, a state, a municipality, as a whole as well as individually, becomes accustomed to sustain good morals, to exhibit good manners and real courtesy, and illustrates a steady advance in true culture, its future and the safety, prosperity, and happiness of its people are assured so long as its neighbours do not forcibly interfere. Its chances of insuring its future despite the interference of others are also improved; for patriotism, intelligence, wisdom and courage are likely to be stimulated amongst such people as nowhere else.

These social remedies will be administered most successfully through the educational system, which takes the child at a tender age, and, when its mind is most impressible, gives it a knowledge of the higher law and learning, and stimulates its moral and its æsthetic senses. The foul seeds which furnish the poisons of the body politic are cultivated by a few within their own families and in the secret club-rooms of anarchist and of the Mafia. Their antidotes cannot be there applied, as a rule; they must be furnished to the whole nation through the education of its children. These antidotes are those which stimulate the growth and maintenance and refinement of those most beautiful products of civilisation,—good manners, good morals, and high culture.

Compulsory application of remedies for social disorders is always a most undesirable though sometimes a necessary course of action. It should be applied, however, instantly and without hesitation, by the constituted authorities when it becomes evident that peaceable and kindly measures will not insure to individual citizens, or groups of citizens, their legal and political and moral rights. Every infraction of law and every breach of the peace should bring its prompt and appropriate check and punishment. Every forcible attempt to infringe upon the rights of a single citizen or a class should be instantly met by the forces of the law and good government and crushed at whatever cost, and should then be followed by prompt and legal punishment of every lawless member of the treasonable party. This is a first principle; for it is upon this principle that the safety of the citizen, his life and property depends.

Industrial disputes should be settled, wherever possible, by arbitrament; but there are many questions which cannot be submitted to arbitration. No man could submit the question of his right to his wife, his child, his house, his land to arbitration. No man could allow any question to be raised regarding the right to offer or to accept what he knows to be for him a desirable exchange, in bargaining, whether in business or for pleasure. No compulsion can properly be permitted regarding any bargain.

Arbitration is entirely right and usually wise where the two parties to a

bargain, disagreeing, are desirous, or at least willing, to submit the question to a board of arbitration in the choice of which they have equal power and in whose judgment they have mutual confidence. But the law and constitution, if the latter were thus framed, would have no moral, and should have no legal, right to prescribe compulsory bargaining. It is better for the nation that an industry be disrupted temporarily than that the rights of citizens should be denied.

The Pennsylvania anthracite strike last year was one of the most famous of social disturbances; it was the first such great social disorder remedied by mutually agreed-upon forms of arbitrament. It was the most serious disorder of that sort ever known to its date, and affected more seriously a greater area and a larger number of people outside the ranks of the disputants, and thus it became better known and understood and awakened a larger public interest than any other dispute in the industrial system of any country of this or of any earlier time.

The dispute was one arising between organised miners and other workers in the Pennsylvania anthracite coal fields, under the official protection of the "United Mine Workers of America," —a combination of practically all the miners of the United States, both bituminous and anthracite—on the one side, and, on the other, the proprietors and executive officers of the whole anthracite district. The points of dispute were many and had long been taking form on both sides.

On the part of the miners, shorter working hours, better pay, both for the day's work and for contract work, better arrangement regarding the measurement of the product of the day's labour, recognition of the union, and various privileges were demanded. On the part of the proprietors and managements of the mines, it was asserted that it was, as a matter of business, impracticable to award higher wages, to establish a shorter working day, or to modify in any important degree the methods or the details of working.

It was claimed that it was impossible to officially recognise the union, composed, as it was, mainly of men whose work lay outside the anthracite fields, and who, officers and men alike, were entirely ignorant of the conditions prevailing in the anthracite fields. It was stated that the influence of the union had been wholly bad, and that it had become already impossible to maintain essential discipline and to carry on the business in a satisfactory and profitable manner, and that conditions were constantly growing worse through the malevolent influence of the union. It was asserted that the union, instead of cultivating a fair-minded attitude amongst the miners, rather sought to make the workmen assume an antagonistic and even actively hostile position and thus stimulated a warfare which was entirely wrong, as well as unfortunate from a business point of view. The interests of the employer and the employee were asserted to be identical, and it was urged that no organisation capable of converting the two once friendly parties to the business into enemies, maintaining, at best, an armed truce, could or should be recognised officially.

The outcome of this dispute between the representatives of the two sides was the appeal of the miners to their national organisation, the consultation of its head with the heads of the local unions, and, finally, when agreement was not reached, a strike which called out about a hundred and forty thousand men belonging to the national union and forced out of employment practically all other miners and destroyed the business of nearly all other industries in the anthracite coal region. It loaded upon the other miners of the country, in part, the support of the men on strike, and diverted large sums of money collected by the unions from their members for the purpose, properly and impliedly, of caring for their sick, aged and impoverished, into the support of industrial warfare.

The result was the cessation for five months of all coal mining in the anthracite districts and the embarrassment of and often, toward the end, the infliction of suffering and death upon innocent

people throughout a large portion of the United States and Canada. It was only when the approach of cold weather threatened the parties to the dispute with similar suffering and risk of life that the fight came to an end.

The results had been enormously injurious not only to both parties to the controversy, but to the country at large. The mine owners were estimated to have lost about $46,000,000 and the miners and other employees about $25,000,000; the transportation companies also lost $28,000,000, while the loss to the nation through disturbance of business, the compulsory closing-down of mills and factories, the going out of blast of furnaces and check upon the coke and other more or less closely related industries, and the loss of working and earning power, through illness and death, directly and indirectly caused by this tremendous disturbance of all industries, has not been estimated, and can be stated only as beyond computation.

The demoralisation of industries is, perhaps, even far exceeded in importance by the demoralisation of the people, not only in the coal regions where law and the principles of good citizenship were most extensively and dangerously infringed upon, but throughout the nation. In the case of the anthracite strike universal uneasiness and distrust and a spirit of antagonism between employer and employee were awakened to an extent without parallel in the history of industry. Brother was set against brother, father against son. The attempt to maintain order and to support the law by use of the police powers of the state was often met with direct resistance, and, throughout the country, by endeavours on the part of the friends of organised labour to destroy the efficiency of the militia by creating a sentiment against the entrance of members of the unions into that essential instrument of protection of the law and of law-abiding citizens. In some states it has since been found necessary to enact special laws forbidding discrimination against union men for thus exhibiting their patriotism. Patriotism was by large bodies of citizens made a crime, and treason was encouraged and upheld.

The report of the commission appointed by the President of the United States with the later endorsement of Congress, which body appropriated the needed funds for its compensation, was made only after a long, careful and minute study of the case, and after receiving the testimony of all available witnesses and hearing the arguments of both parties to the dispute, represented by the ablest counsel.

It covered all the specific questions raised, and a discussion of the details of the testimony and of the principles involved from the point of view of law and of equity, as well as of economic and criminal law. It was decided that it would be right to raise somewhat the wages paid in the anthracite coal fields, to shorten, in some cases, the length of the working day, and to adopt, in other cases, a sliding scale of payment of coal produced, basing the scale upon the prices obtained for the coal at tide-water in New York Harbour. It was reported that the pay previously given was not by any means as low compared with that of other vocations as had been claimed, and that the workers in the mines were able to adopt a scale of living fairly comparable with that attained by labour of similar grade in other occupations or in other coal fields. It provided for a conciliation commission to settle disputes that might later occur, and that the agreements made under the award should hold until 1906, the advances dating from November, 1902. This should be followed by other and new agreements made by mutual understanding.

The decision forbade discrimination between union and non-union men, abolished the "Coal and Iron Police" employed and paid by the mine owners, recommended new and better laws against the employment of children, and advised state and national laws providing for compulsory investigation, but not of arbitration, of future contests of a similar sort.

The conclusions reached by the commission as just summarised were given

broadest statement in the final sections of the report in which the general principles involved were discussed.

Regarding lawlessness, such as so extensively characterised this great contest, it asserted that no industry is more dependent, for its success, its safety and its non-interruption, upon discipline than is the vocation of coal mining. It is a dangerous and a troublesome work at best and in the most skillful hands and directed by the best of supervision. None other is more dependent upon mutual understanding and mutual support in the maintenance of discipline. "Discrimination and interference weaken all discipline." The most rigid and efficient discipline should be established and maintained by the co-operation of both employer and employed.

The calling out of the militia was a justifiable, a reasonable, an entirely proper, and, in fact, a necessary, act. "No peaceable and law-abiding citizen has reason to fear or to resent the presence of either,"—guards or militia.

Absence of protest and of active resistance on the part of law-abiding citizens is an encouragement to disorder. The law can make no exceptions, and it must use every available power to maintain itself and to preserve the peace. Peaceable striking is not contrary to law or to reason; but a strike set on foot with the purpose of forcibly compelling all opposition to cease until it gains its object "violates the law from the beginning."

A large strike always tends to encourage lawlessness and to engender crime. The organisation bringing about such strikes voluntarily accepts these risks and this responsibility, and is bound, in law and in justice, to provide against and to prevent such results. "Only so can they deserve and attain the respect of good citizenship. A labour or other organisation whose purpose can be accomplished only by the violation of the law and order of society has no right to exist."

The right to work or to remain at work, to cease work or to go to work under any conditions, themselves not in conflict with law, cannot be rightfully or lawfully denied or restricted, whatever the character or the opinions of the worker or the would-be non-worker. In that matter every man is a law unto himself, and has a right so to be, at all times and in all places, in time of strikes or at any other time. Compulsions exerted to sustain or to destroy a strike are alike "immoral and anti-social." Concerted attempts to restrain the liberty of the citizen in these respects constitute "a conspiracy at common law," and should be punished as such. The "boycott" is condemned as "tyranny, pure and simple, and, as such, hateful."

The claim that the conditions affecting a strike are those of "war" between the parties to the dispute was made, but this is denied by the commission. "There is only one war-making power, and that is the government. War between citizens is not to be tolerated, and cannot, in the proper sense, exist; it is unlawful, and it is to be put down by the sovereign power of the State and the Nation."

The "black-list" is condemned with the "boycott." Both are cruel and cowardly. Finally, "it is adjudged and awarded that no person shall be refused employment or in any way discriminated against on account of membership or of non-membership in any labour organisation."

The future of labour organisations, during the period of strife and excitement of the Pennsylvania anthracite miners' strike, seemed to many onlookers extremely uncertain. It appeared as at least a possibility that but one of two developments could occur,—either the labour unions would succeed in mastering the whole organisation of the industries and would bring about chaos by depriving it of its generalship by talent evolved by experience and proved ability from the midst of the whole body of citizens; or a worse chaos, anarchy, would be caused by the destruction of the body politic and the provocation of strife without control of law, and with the result of destroying law and order and all safety of property for an indefinite period. On the other hand, should

the unions lose in the great contest, it was feared by many good citizens that it would be impossible for the employees to secure even a fair share of the product of their part of the wealth produced by "the triple partnership, labour, capital, and ability," and that, consequently, the country and the world would be checked, if not turned back, in the path of progress.

The outcome of this particularly threatening and injurious contest, however, while revealing the fact that such struggles are liable sometimes to cover so large an extent of territory, to affect so large a fraction of the industrial system, and to involve such important industries as to produce most costly and dangerous effects, indicated that there, nevertheless, may be found peaceful and righteous methods of settlement, so that the outcome may, in the end, cause important and desirable improvements in the methods of conduct of business, and bring about better conditions of life and work for the protestants against the older conditions.

The organisation of the union has been already modified by these events, and a revolt against lawless and unfair methods of prosecution of the purposes of the organisation itself has been consequent upon these unhappy experiences. Unions had been long in existence, both in the United States and in Great Britain, which had recognised the inherent wrong in strikes, lockouts, and especially the evasion or infraction of the law and the provocation of disorder and attacks on the rights of the citizen. Law and order above all had been the motto of a considerable number of such unions, where the most intelligent and patriotic and prudent of employees had been banded together for the peaceful accoplishment of rightful purposes. Their constitutions and by-laws had sometimes explicitly declared for correct moral, legal, and economic methods. All the older and most successful unions had long exhibited a tendency in this direction, and the greater their experience and the more intelligent and skillful their administration, the less the requency of resort to force or to compulsory bargaining. In one case, that of a union formed after the close of the struggle just described, the organisation was incorporated, and its articles of incorporation include this declaration of principles:—

"This association shall encourage industry, economy, thrift, and honesty among its members; maintain amicable relations between employees and employers of labour; assist its members in ob aining the highest wages consistent with the general good of all concerned; promote all forms of productive industry and increase the employment of labour at good wages; prevent unjust and unreasonsble discrimination against any of its members by any person, combination, or conspiracy to prevent such members from securing employment in any branch of industry, and protect and defend its members against any and all attempts by any person or combination of persons to abridge the inalienable right of all mankind to work for such wages as shall be mutually satisfactory to the individual workman and his employer."

Legal incorporation is coming to be more generally recognised as both fair and wise, and the deliberate assumption of legal responsibility for the acts of the organisation is becoming more usual. The courts are also forcing this responsibility upon all organisations.

The administration of organisations, both of employees and of employers, must be probably steadily improved by the recognition of the fundamental principles of law, equity, and economics by their members. Mutual agreement, after careful and fair-minded deliberation over the respective rights and needs of the parties to industrial disputes, must probably supersede, ultimately, all attempts at compulsory bargaining, and the absolute contradiction of these terms will be well understood as soon as both sides begin to deliberate in a friendly spirit. The common interests of both parties in maintaining, uninterruptedly and efficiently, the steady operation of every industry under conditions assuring the opportunity to every individual to contribute in maximum degree through his individual ability and talent, and giving him every opportunity to advance to the position in which his talents and his character may have full play in promotion of the good of all, is becoming understood and admitted, and the administration of all organisations of whatever kind or character on such principles may be hoped for in the early future.

The methods of operation must ulti-

mately become those of parliaments seeking the best and most correct, just and efficient ways of promoting common interests and of reconciling conflicting claims The organisation of industries and the organisations of employers and of employees will be found to have common and perfectly reconcilable purposes, and the good of the people of all classes and vocations will be found to be subserved by the adoption of legal and equitable systems of procedure. The most intelligent, conservative, wise and prudent individuals will necessarily ultimately control and lead the organisation, and the progress of the industries will be proportional to the spread of intelligence, patriotism, honesty, and fairness amongst the membership. When the growth of this system of studying and of handling industrial problems shall have brought about in maximum degree steady industry for the masses, utilisation of individual capabilities and opportunity for gravitation of talent into places of responsibility, the whole industrial system will become, in the highest degree, efficient. Then, and only then, can the nation attain its highest position on the scale of civilisation and its people become in the highest degree wealthy, comfortable, contented, and happy.

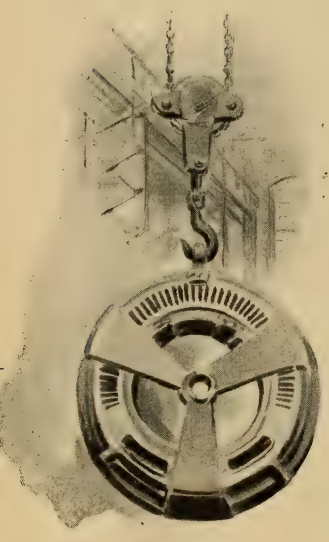
The coming problems are thus those of promoting the advance of the nation to the highest point of industrial efficiency and the resultant assurance of greatest prosperity, content, and intelligence. Only where a nation is in maximum degree wealthy, and its people, as a mass, comfortable and competent to think out the problems of its time, can a real and a permanent higher life be assured. The whole history of mankind is an illustration of the growth of these principles and of the progress of the race in proportion as they are more generally recognised and acted upon. Invention, progress in the arts and sciences, and growth of education, of general intelligence, of wisdom and of culture conspire in the promotion of the highest and best interests of all.

The place of the engineer in this progress is obvious, and his course is as inevitably toward a leading position in this march of an industrial army toward its goal. He has for his task in the future, even more than in the days of Watt and Smeaton and Telford, the organisation of the industrial army and the officering of the host. He, as the educated and professionally trained representative of applied science and of ability, the most essential element of the trilogy in which labour, capital, and mind play their several contributing parts, is expected to provide the learning and practical acquaintance with the laws of Nature which must always be relied upon for the wise direction of all these mighty forces of industry. He must see that the machinery of the industries is supplied, that it is properly adapted to its purposes, that the organisation of the industrial army is complete, logical, systematic, and efficient, and that the great industrial operations of the world are carried on with the highest possible efficiency, producing a maximum, minimising all wastes of time, labour, material, capital, and brains.

His place is one of enormous responsibility, and it is his duty to see that he attempts only tasks that are within his range as an expert, and that he is himself properly prepared, by education, experience, and evolution of character, to perform his task with satisfaction to himself and with advantage to the world.

MODERN FACTORY TRACTION

By Clarence J. Messer



FORCE is the basic scale on which present day success must be written, and concentration is the keynote. This is an era of unprecedented competition, and, whether it be the aggregation of legal talent which delves for title of realty for a modern sky-scraper, the coterie of capitalists who would set industry humming, or the small manufacturer on his country water-power, all ears are straining to catch the pitch of the tune.

Industrial properties which a decade ago were returning satisfactory interest on the investments are now out of date. The arrangement is faulty to meet new conditions of output variety. Machinery is being renovated and replaced by latest inventions. Waits and sharp turns between machine and machine are being abolished. It has come to be acknowledged that an absence in availability of product is a serious hindrance to an economic sequence.

The minutest inspection is demanded from the engineering profession for the discovery of "leaks" in earning capacity, and the manager inquires to the fraction of a penny into the expense attendant on each individual department which goes to make up his whole. Natural advantages are zealously guarded and developed. Methods are compared in the hope of securing the slightest curtailment in operating cost, and new devices which may possibly increase the profit on the yearly output to the extent of even one-fifth of a penny to the pound receive most thorough examination. One of these devices, which is attracting more than ordinary attention in all lines of manufacture, is the system for comprehensively bringing all departments of a plant into an economic handling relationship with each other, called telpherage.

The March, 1902, number of CASSIER'S MAGAZINE contained a most complete descriptive article on telpherage; consequently it is not the intention of the present writer to attempt an elaboration on construction detail where the field has been so ably covered. It is, instead, in an effort to illustrate the causes which have drawn to telpherage special notoriety at this time of ultra-scientific manipulation of producing properties that the subject is again introduced. Possibly the engineer and manager of the industrial venture which has lagged in the run for economical supremacy may, in reading between these lines, find an antidote for influences which are sapping the life of his plant.

Even a casual investigation as to the possible income-developing properties of telpherage will set the prudent manufacturer inquiring into his own seemingly impregnable position. There may be "leaks" which have long lain covered. He is brought to this conclusion when he observes that a new datum for economic reckoning is established through a principle which permits of the free ingress and egress of freight with but one handling, at any point from basement to roof throughout his premises. The first lesson in his new primer dem-

onstrates that two men can receive material at any plane in a height of 60 feet, convey it a quarter of a mile, and deposit it on any plane in the beforementioned height, accomplishing in a ten-hour day the movement of 250 tons. His past expense sheets are familiar with this performance to the extent of the wages of ten men and the keep of four horses.

He will find that at a primary expense not exceeding the cost of his six teams, economy of storage space. A little calculation on his part will convince him that with an additional primary expenditure, the interest on which would not exceed the cost of one of his horses, he can equip the telpherage plant with a self-filling bucket of such capacity that the cost of his storing may be reduced to one cent per ton.

The conditions in the instance quoted are identical with those which might exist at any manufactory which has the

AN AUTOMATIC TELPHER LINE FOR COAL AND ASHES

which are storing his coal at twenty cents per ton, he can install a telpherage plant which, at the rate of 10 tons per hour, will store 5000 tons in an area 150 by 30 feet, the entire cost of his raising, conveying and storing being less than six cents per ton. Here are presented to him three distinct economic propositions, viz., the nominal fixed charges in proportion to the volume of work performed, the effect of rapid and constant handling of coal on the vexing question of demurrage, and the unprecedented benefit of railway service and a small area on which a telpherage trestle 40 feet high could be erected. To connect such a coal store with the boilers is but a matter of trackage supported by telegraph posts every 25 feet, and at another extremely low tonnage cost the 5000 tons may be deposited into elevated bins above the boilers 600 feet away, where chutes deliver the coal to the automatic stokers or place it, in quantity desired, on the boiler house floor in a convenient location for firing.

THE CABLE TRACK IS PRACTICALLY LEVEL, DUE TO DOUBLE SUSPENSION, WITH A FULL LOAD OF CASES OF COTTON FROM THE MILL ACROSS THE RIVER TO THE OTHER BUILDING

Necessitated economy of space has brought many inquiries from all parts of the country concerning the 1000 to 5000-ton bulks which constitute a standard type telpherage coal storage. A uniform piling height is secured in these standard types through the medium of a travelling telpher track, onto which the telpher with its load is run, and from any location on which the dump can be made. The travelling track serves every requirement of area covering as completely as would be done by a moving electric crane. At a very reasonable primary cost a self-filling and self-dumping telpherage installation will hoist coal from a car or barge, store it to a level of 18 feet in a bunker 200 by 25 feet, at an operating cost, including interest and depreciation, of three cents per ton. This 2500-ton bunker will supply ample storage capacity for a plant consuming 25,000 tons a year. The instances here considered are what might be termed intermittent storage in contradistinction to large uninterrupted handling. In the latter work a fraction of a cent tonnage cost may be secured by the equipment of proper telpherage machinery.

The progressive president of a large illuminating plant in a conversation with the writer once expressed a thorough knowledge of what was needed to satisfy his requirements. "But," he concluded, "I have heard of no apparatus on the market which will allow me to bring my several planes of operation into a comprehensive, and at the same time economical, grasp. I not only need a conveyor, but one which will handle

anything anywhere in a height of 50 feet."

Later the gentleman found all necessities supplied in telpherage, through an installation of which he has practically doubled the efficiency of his plant. His coal gas retorts, water gas retorts, screens, crushers, ash dump and coke store, although the individual serving points vary in location from planes 9 feet below to 40 feet above ground, have been connected for handling so as to produce of the whole an economic problem as simple as any single feature in his actual manufacture.

It would be impossible to accurately compute the profit derived from this installation. The reduction in money expense is but a small part, though twenty-five men and four horses would not accomplish the work done by the machine and its two operators. A continuous working day of twenty-four hours has been made possible through the installation, and the two telphermen relieve each other in the day and night shift. From the quenches, 6 feet below ground, 1400 pounds of coke are delivered to the charging holes of the water gas retorts, 40 feet above ground, the operation consuming but three minutes. Without telpherage this feat is an impossibility.

The various operations are performed with constancy and rapidity, and time is left in which to convey fuel for the boilers. The coke which is not dumped to the crushers and screens over the coke pocket, 45 feet high, or served to the water gas retorts, is conveyed to a surface store, from which, as needed, it is again hoisted to the screens for working. Duties are performed by telpherage which previous to the installation had no existence, but which, having been made possible, tend to produce that result in the yearly balance sheet which all live managers and presidents are

THE BUCKET IS LOWERED UPON THE COAL OR LIKE MATERIAL AND GRABS IT. THE ELECTRIC HOIST CLOSES THE BUCKET AND RAISES THE LOAD WHILE THE TELPHER DOES THE CONVEYING

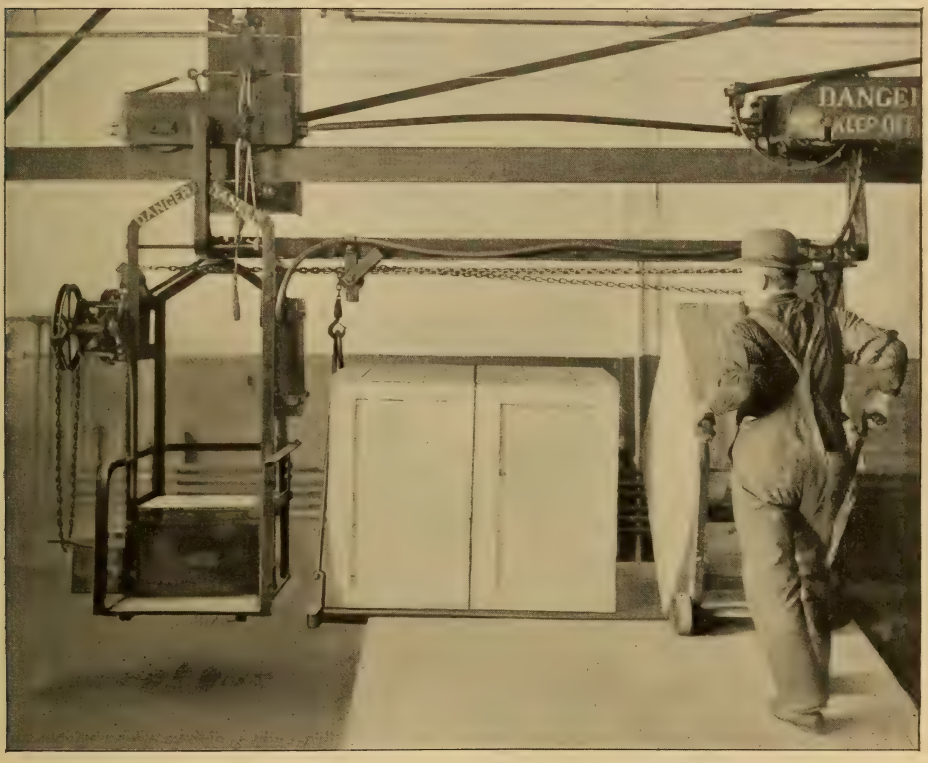
THE TRUCK, BEING ELEVATED, IS ABOVE ALL OBSTRUCTIONS AND OCCUPIES NO VALUABLE GROUND SPACE. LOADS CAN BE TAKEN FROM ANY STORY, THEREBY AVOIDING THE NECESSITY OF LOWERING GOODS TO THE FIRST FLOOR FOR SHIPMENT

striving for. For the foundry telpherage is presenting peculiar qualifications. In storing pig, unloading it from cars or selecting metals for the cupola, a telpher with its operator will accomplish the labour of eight men. All manual lifting is abolished, as the platform on which the material is conveyed is instantly put on the level from which it is to be removed. The electric hoist, which is a fixed adjunct of telpherage, does all the raising, the telpher the conveying. When arriving at the cupola the hoist raises or lowers the load to the proper working distance with the furnace door. From a travelling platform with a capacity of 5000 pounds of various metals there may be a successive charging of many cupolas.

For a moulding house two distinct

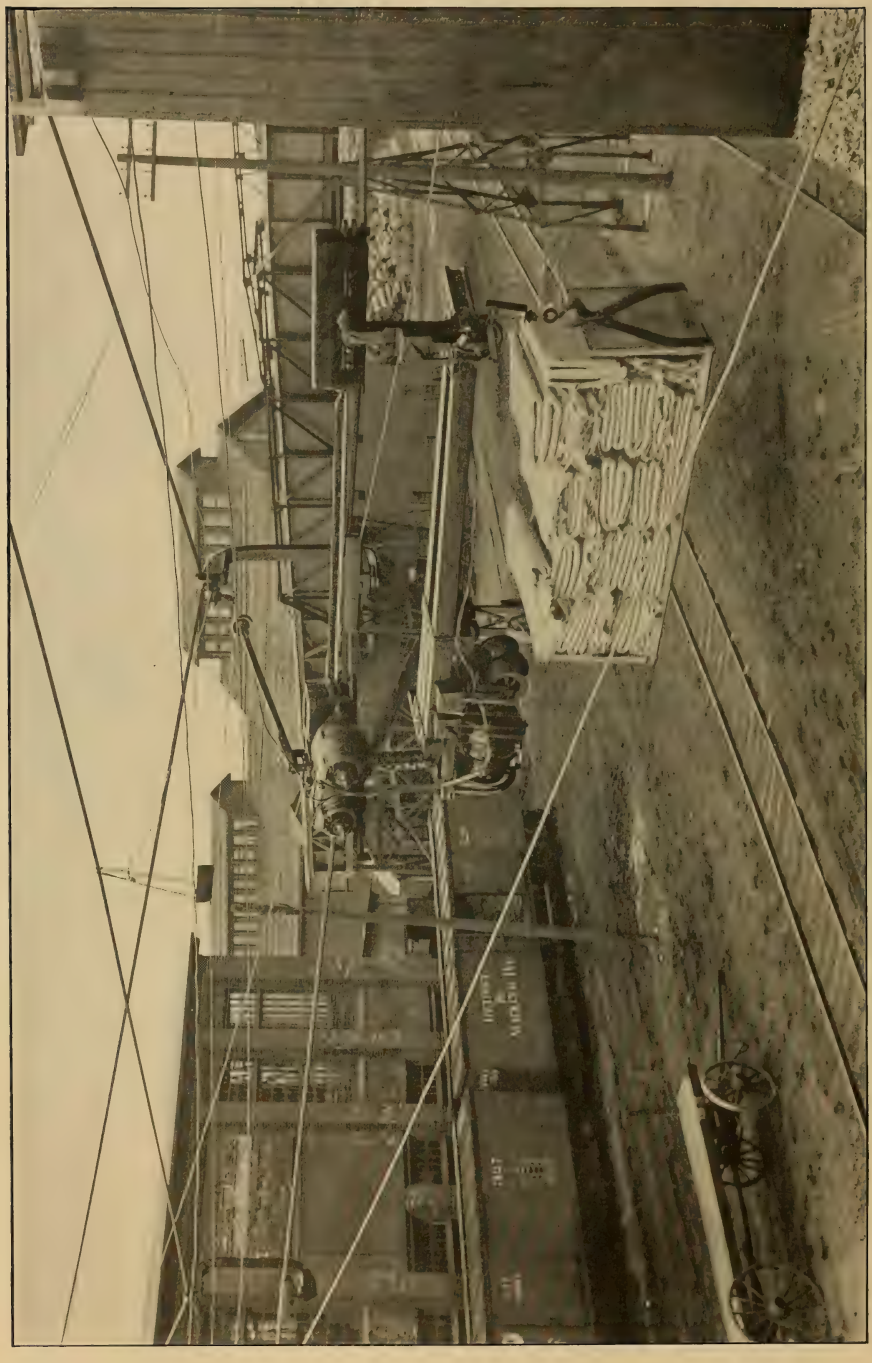
advantages may be said to owe an existence to telpherage. The cost of a night gang of casting movers may be eliminated from the pay-roll, and a 50 per cent. greater efficiency may be secured through the possibility of conducting the operations of casting and removing castings from the floor at the same time. The telpherman grasps a cooling casting within the range of his electric crane or travelling telpher, and, raising it beyond possible interference with the work of casting which is progressing below, sends it out of the building and away to the sand blast or the tumblers, the entire operation consuming but three minutes. With his apparatus and one helper to handle his chains, the telpherman will perform the work of eight men and a pair of horses in this feature of the business.

The conveying of castings from the cleaning rooms to the shops or storage, the disposal of the worked sand, the carrying of moulding boxes to and from the yard, —all these manipulations may be materially reduced in cost through a telpherage installation. Conveying 100 or 5000 pounds, the telpherman can work his hoist at 60 feet to the minute, and make his horizontal run at from 300 to 1000 feet a minute.



AVOIDING THE NECESSITY OF PLATFORMS IN LOADING CARRIERS WITH CASES. THE CARRIER SWINGS JUST CLEAR OF THE FLOOR AND THE INCLINED PLATFORM ENABLES THE CASES TO BE DUMPED FROM THE HAND TRUCKS DIRECTLY UPON THE CARRIER

In cotton manufacture this system has earned an enviable reputation. The elevated rail allows unimpeded transit, even winter's snow and sleet offering no barrier to constant operation. Where formerly half a dozen yard men were overworked half a day and helped the team of horses to " put in time " for the other five hours, it has been found that on account of the instant and rapid ac-



GOODS IN TRANSIT FROM ONE MILL TO ANOTHER DURING PROCESS OF MANUFACTURE

TELPHERAGE UNLOADS THE SHIP AT THE WHARF, OR THE CAR ON ITS SIDING; DEPOSITS THE COAL IN AN ELEVATED COAL POCKET OR BIN AND ON THE STORAGE GROUND. ONE MAN ATTENDS TO ALL THE HOISTING, CONVEYING, AND DEPOSITING

tion of telpherage the telpherman alone is not kept fully employed. Telpherage has taught the cotton mill agent that unskilled labour is an unnecessary expense. The producing artisan stacks his product on whatever floor of the mill he may be working and telpherage takes it to the packing rooms. The bale of cotton is taken from the car or storehouse and placed directly on the picker house floor. No trucking to and from elevators is required, the hoisting, conveying and depositing being conducted through a continuous movement, even though the terminals are stories apart. Storehouses on opposite sides of a river are practically joined. Heavy drums of caustic, carboys of acid, coal, —everything about the plant which requires movement receives an economic handling by this machine.

There are many other illustrations of like moment which lack of space must preclude from this article. One other instance, however, should receive mention. At a manufactory where an immense amount of sand is daily handled a telpherman with his self-filling bucket is doing the work which once occupied the entire time of sixteen barrowmen.

The cost of the effort under former conditions was at least $20 a day. Under the new method $6 pays the bills.

The American Indian established a principle in weight handling when he transferred his corporeal possessions from place to place on two poles, affixed at the one end as shafts to his horse, the other end dragging and receiving the full resitance of the earth. In the waggon and coach this method was greatly developed; still, even when the railroad became an institution, the Indian's principle maintained. The earliest experimenters for a conductor method of electric traction generally agreed that a line for aerial transport would furnish the least obstructions to the peculiar requirements. A connected train of small units which conveyed ore, and which consisted of cars suspended from 70-foot stretches of a strong wire cable, formed the introduction of telpherage, and an inversion of the principle so long ago furnished by the Indian. The telpher load is carried below the trucks.

The crude locomotive, "Puffing Billy," that bumped along over a stone track nearly a hundred years ago bears as close a resemblance to the present magnificent iron horse as does that first crude, clattering installation of telpherage, with its speed of four miles an hour, to the powerful and ornamental machinery with which, in three minutes, the present-day manufacturer passes his 1000-pound parcel from a freight car to an operator in the fourth story of his factory, 800 feet away.

Telpherage, notwithstanding its disadvantage in age for ripening, has, perhaps, made the greater progress of the two transportation methods; for while the province of the former is, as in the beginning, confined to hauling or pushing weights, the latter has increased that province by two distinct mechanical movements, and so completely under the control of one person are all that they can be operated in a small fraction of the time which, in ordinary factory conveying, is usually expended on any one. To illustrate,—the raising of a 1000-pound case of goods to a waggon platform will take four men at least ten minutes. A telpherman will hoist the case 30 feet in three-quarters of a minute. To transport a ton of this material 1000 feet by men and team will occupy twenty minutes in the loading, ten minutes for round-trip hauling, and twenty minutes for unloading, if the goods are to be delivered to the ground floor. The telpherman covers the distance in one minute, and his speed on hoisting and lowering is the same.

The cost of handling a ton load of two cases by the men and horses would be 52 cents. Telpherage, at a cost of 20 cents, will handle nine tons in the same time. In the first instance a half day's labour shows a movement of five and one-half tons at a cost of $2.86. By telpherage the five hours gives a movement of fifty tons at an expense of $1.85. Nor does this end the comparison. In stacking cases the efficiency of the man outfit is greatly reduced, while that of telpherage is increased. Still further, the telpherman can deliver the goods to the operator wherever he may be, and there is no necessity for an elevator attendant, who puts on another charge for handling.

There are to day but few manufacturing plants which are without an electric lighting dynamo. Six horse-power from one of these 110 or 220-volt currents will suffice for all but the heaviest telpherage conveying. The scope of telpherage embraces installations for handling 10 tons per day to 400 tons in an hour. Either problem may be solved with surety and economy.

PROFIT-SHARING AND THE PREMIUM PLAN

A SUGGESTED PLAN OF PROFIT-SHARING BASED ON THE PRINCIPLES OF THE PREMIUM PLAN OF PAYING WAGES

By Kenneth Falconer

THAT no plan of profit-sharing yet devised has given wholly ideal results in harmonising the relation between workman and employer,—in eliminating friction between them,—and in securing the best efforts of each for the good of both, will be readily admitted. Whether this is because of some inherent defect in the idea itself, or imperfection in the methods of its application, or because of the difficulty of finding a fair and equitable basis upon which to determine the division of profits, is still an open question.

The plan here offered is suggested not as one from which perfect results may be expected, but as one which would appear to be based on fairness and equity. By-standers see most of the game, and in the great game now being played between capital and labour a suggestion of some value in its influence for fair play may possibly come from an unbiased and totally disinterested spectator.

Sincere attempts to better the relations between workmen and employer have in many cases resulted in the provision, for the former, of greatly improved surroundings and conditions in connection with their daily work, and also in many cases with their home life and social opportunities. Work along these lines is broadly and generally referred to as industrial betterment. In other cases the same end has been as sincerely, and perhaps as successfully, sought by different methods of adjusting the wages paid, so that any increase in the output, caused by the efforts of a workman, results directly and proportionately in an increased wage to the producer. In addition to plans of industrial betterment and attempts by means of a flexible wage rate to secure and maintain a fair ratio between wages and product, a division of profits between workman and employer has been tried with sometimes more, and sometimes less, satisfactory results.

Recent writers on the industrial condition are suggesting that the unions, as representing labour, shall acquire stock in the various industrial enterprises with which their members are connected, and so secure, to some extent, a voice in their control and management. This, however, is generally looked upon as intended to create a business relationship not between individual employees and their employer, but between labour as a whole and capital as a whole. The aim of the writer, on the contrary, is to increase the interest of workmen in the success of the company or firm with which they are engaged by establishing a business relation between their employer and themselves, individually if possible, collectively if not.

That plans of industrial betterment have in individual cases resulted in benefit to both workman and employer cannot be questioned. That the good attained has been in direct proportion to their extent cannot be admitted, and neither their advocates nor their opponents will claim that they contain the elements, or are based on the principles, of a straight business proposition between man and man. Up to a certain point proper conditions, surroundings, and even proper social opportunities are the workman's right,—a right which he is entitled to expect from those responsible for the conditions in which he may

be working and living. When they pass that point they become simply gifts, and however tactfully given, or willingly received, their effect is rather to weaken than to strengthen the connection between the interests of the workman and the employer.

Of all modern systems of paying for productive labour the premium plan stands pre-eminent for fairness of principle. Its central idea is that the gain due to increased product by a workman be divided between the workman and his employer. If the principle of the premium plan be correct, as regards wages paid for labour, the application of that principle to profit-sharing should result in a plan by which profits realised on productive labour are shared between the workman and the employer. The sharing of profits on such a basis that the producer will have a direct and proportionate financial interest in that portion of profit which is realised on his labour would appear to be a fairer and more equitable basis of division than the setting aside of a certain arbitrary amount or percentage to be distributed among employees.

A very common objection to the majority of profit-sharing plans is the supposed necessity of waiting until the end of the fiscal year before the actual profits can be ascertained and the distribution made. The writer says "supposed" advisedly, for in any manufacturing business of moderate size a proper system of shop accounting should show the actual profits each month, and there is no reason why they should not be distributed monthly, the workman's share being paid the month following that in which the profits are made. It is proper here to call special attention to the fact that a profit is not made on completion of manufacture, but only when a sale has been effected.

Cost of production is admittedly composed of wages, material, and a certain amount of shop and manufacturing expenses, and in the first item alone lies the business relationship between a workman and his employer. The cost of the material of which a given article is manufactured is entirely the concern of the latter, as are also the expenses incurred in manufacturing it. Whether the profit on these two elements of cost is great or little is no affair of the workman, nor can the workman fairly lay claim to any share of such profit.

The wage cost is a different matter. Any profit on this element of cost, realised by the sale of a manufactured article, is secured as a result of the efforts of both employer and workman. Neither could secure it without the other, and this alone is the profit of which labour can claim a share with any sense of fairness or show of equity. Assume that a manufactured article sold for $40 upon which a profit of $8 is realised. Analysis of the cost of such article and the profit made upon its sale may result as shown in Table I, even figures being used for the sake of convenience.

TABLE I.—ANALYSIS OF PROFIT REA'ISED ON THE SALE OF AN ARTICLE COSTING $32 AND SOLD FOR $40

Detail of Cost		Sold for	Profit	% Profit	Analysis of Profit
Wages	$10	$40	$8	25	$2.50
Material	10				2 50
Mfg. expenses	10				2.50
Selling expenses	1				.25
Administ've ex..	1				.25
Total	$32	$40	$8		$8.00

The material of which this article is composed is entirely the property of the employer. The indirect outlay incurred to manufacture it, the expenses of selling it, and the general administration of the business are his concern alone, and his alone should be the profits made upon the expenditures in these various directions. As regards the wage cost of the article manufactured, the employer furnished the money, and possibly the business ability necessary for its production; the workman supplied the labour and the skill, and it is only the $2.50 profit realised as a result of the combination of these four factors working together that should be distributed between the workman and employer if profit-sharing is to be adopted on a business basis instead of as a gift proposition.

It is not the writer's intention at present to go into the working details of this idea, or to take up the question of the amounts involved. The point to be

made is this—Supposing labour to be recognised as an equal partner with capital in the manufacture of a given article, that article contains only one element the profit on which should be shared, namely, the wage cost,—this, quite irrespective of any question as to the amount or proportions of profits involved. Obtaining the data necessary for a distribution of profits on these lines would simply be a matter of installing an efficient cost system, or of modifying an existing one.

Reduced costs mean increased profits; increased costs, lessened profits. A workman's efficiency tends to reduce the wage cost; his inefficiency, to increase it, and it is in connection with this that the principle of the premium plan enters into this method of profit-sharing.

Tables II, III and IV assume exactly the same conditions to exist in each case, except as regards the wage cost, and show that the profit earned by the workman varies in direct proportion to his efficiency as evidenced by the length of time taken to manufacture a certain article. That this system could be adapted to distribute the employees' share of profits among the individual workmen according to the labour each had expended is not probable. Possibly in exceptional cases even this could be done. It could, however, certainly be used as a basis of distribution of profits among all workmen employed directly on productive work. The profit earned each month might be distributed as a ratio of the productive labour for the month, or for the preceding month, or on an average covering a certain period of time, as might be found best.

To go a step further, the sales might very easily be classified to agree with the productive departments or shops, and thus afford a basis for dividing the workman's share of the profit on each class of goods among only such workmen as are concerned in the manufacture of that class. This would be a more equitable plan than to distribute the entire profit,—that is, the workman's share of it,—on the productive labour, even if it be found impossible to establish a ratio for individual workmen.

These, however, are merely working details. As far as the principle of the plan is concerned, in the tables shown workmen may be taken to represent either the individual, or those engaged in the manufacture of a certain class of product, or all workmen engaged in productive labour irrespective of shop or department.

TABLE II

Cost		Sale	Profit		Profit on Wage Cost	Distribution Workman	Distribution Employers
	$	$	%		$	$	$
Wages	4				2.00	1.00	1.00
Material	4						
All expenses	4						
Total	12	18	50				

TABLE III

Wages	2				1.60	0.80	0.80
Material	4						
Expenses	4						
Total	10	8	80				

TABLE IV

Wages	6				1.72	9.86	0.86
Material	4						
Expenses	6						
Total	14	18	28½				

SUMMARY.—Workman's rate of pay assumed to be 20 cents per hour. Results to him are:

	Profit	Investment	Profit per unit invested
Table II	$1.00	20 hrs.	0.05
" III	0.80	10 "	0.08
" IV	0.86	30 "	0.02 26-30

The writer has tried to outline a plan of profit-sharing based on the principles of business, not of gift. Until all element of gift is removed from the relation between workman and employer and a fair business basis substituted, profit-sharing will be only a palliative, not a curative, measure for friction and dissatisfaction in so far as shops of small or medium size are concerned.

VICKERSTOWN

A MODEL INDUSTRIAL SETTLEMENT

By a Staff Correspondent

A CONSIDERABLE industrial exodus from London has been in progress for several years, but having been gradual it has failed to attract attention in the public press. Many provincial towns,—Bedford, Rugby, Preston, Chester and others have been chosen as the venue for works, hitherto Metropolitan, because on economic grounds the London sites are too valuable, and in consequence of the congestion of population the taxes are too great to justify the continuance of workshops requiring a large area for carrying on effectively the processes of manufacture. The change is commendable from another point of view; it would in some measure relieve the congestion experienced by workers in such departments of commerce as are indispensable to London. The chief difficulty militating against a further transfer of factories to the country is the impossibility of ensuring satisfactory and cheap housing accommodation. The setting up of an establishment for 2000 or 4000 workers creates a demand for houses which profits the rack-renter and jerry-builder, excepting where the employer courageously accepts responsibility. There is, however, a lack of experience, and nothing checks progress on such lines so much as uncertainty.

Much has been written as to Port Sunlight and Bourneville; but in these more or less of philanthropy has been introduced, and where high-minded, trained mechanics are involved the difficulty from this standpoint is great. Education and skill tend to create in the working man a spirit of independence which in turn begets a jealousy towards all movements originated by employers. But a scheme meeting such a case has been carried to success at Barrow-in-Furness by the creation of Vickerstown, of which little has been published. The main interest of this project from the public standpoint is that it offers an important alternative to more or less philanthropic undertakings. In Vickerstown there are about 1000 houses occupied, as compared with 400 at Bourneville, and about 600 in Port Sunlight. The capital cost involved in Vickerstown is nearly half a million sterling.

Vickerstown, as the name suggests, has been organised by the famous shipbuilding, ordnance manufacturing, and armour-plate making firm — Vickers Sons & Maxim, and is a result of the development made by the company at the Barrow-in-Furness Works which were taken over about six years ago and enlarged to such an extent that the house accommodation in the town proved quite inadequate. The number of workers has more than doubled in four years, being now over 10,000. Under these conditions difficulty was experienced in inducing skilled and reliable men to go to Barrow in-Furness, and the directors recognised that they were more likely to secure the ideal home influences conducive to capable and contented work on the part of the men if they themselves constructed the houses rather than by leaving this to private builders. But at the very inception of the undertaking certain economical conditions were laid down, and at a time when sociologists are exercised on this question of the housing of the people a solution by men of such great commercial experience and probity as the Vickers and their colleagues is worthy of close consideration.

It was, I understand, laid down as an

JAMES DUNN PARK IS THE POPULAR RESORT OF THE PEOPLE OF VICKERSTOWN. EVERY SUNDAY AFTERNOON CONCERTS ARE GIVEN THERE

BY COURTESY OF JAS. C. FERGUSON, VICKERSTOWN

SOME OF THE HOUSES IN MIKASA STREET, VICKERSTOWN. FROM THE LOBBY, ENTERING THE FRONT DOOR, THERE IS ACCESS TO THE FIRST FLOOR, THE KITCHEN, AND THE PARLOUR, WHICH IS 14 FT. BY 15 FT. WITH A BAY WINDOW. THE SIZE OF THE KITCHEN IS 13 FT. BY 16 FT., OUT OF WHICH ONE ENTERS THE SCULLERY, WITH A DETACHED WASH-HOUSE IN THE YARD. THERE ARE THREE BEDROOMS, THE LARGEST BEING 13 FT. BY 14 FT., AND A BATHROOM. THE ELEVATION IN THE FRONT IS A RED SAND STOCK BRICK BASE WITH ROUGH-CASTED WALLS ABOVE, SURMOUNTED WITH RED TILES ON THE ROOF, AND DEEP OVERMOUNTED EAVES

BY COURTESY OF JAS. C. FERGUSON, VICKERSTOWN

essential that the scheme must be self-supporting, although the directors recognised that, as it must yield an important indirect influence on the efficiency and economy of the work done by reason of pleasant home environment, the resources and financial credit of the company could be utilised to further the scheme. While a small return was required for capital,—something equivalent to bank interest,—no profit was looked for. On no other basis can housing schemes be considered sound; an employer may choose to offer financial assistance without seeking return, but such assistance must be debited under some form to the manufacturing account, and such charge, without parallel in the case of less philanthropically-inclined firms, is a handicap in the competition inseparable from modern business methods. Moreover the influence on the worker must be considered; the effect on his independence is an important factor. The fact that Vickers's workmen have been trained to form great masses of metal with a precision which does not admit of variations greater than the ten thousandth part of an inch, introduces into the problem a psychologic element which may not present itself in the case of other workers; the spirit of independence only yields to treatment on sound economical lines.

The Vickers Company have attracted to their service the most skilful staff for management, scientific research, design, and practical work and have secured their loyal co-operation largely by paying adequate salaries. While the interest of such men in their work may be quickened in several ways, the oldest and still the most effective method is the payment of a fair day's wage for

a fair day's work. This is the surest foundation on which to build mutual respect and mutual interest, and it has been the *motif* of that relationship between the Vickers Company and their staff, which has proved so successful in the past. All organisations in the interest of the workers secure the co-operation of the directors and managers, but they must be self-supporting and must be managed by the men.

Another important condition, determined at the outset, was that no house was to be sold. The prudence of this resolution is indicated by the fact that in Port Sunlight some of the workmen

THE SHOP IN THE FOREGROUND IS ONE OF A SERIES OF EIGHT, BUILT TO SATISFY THE NEEDS OF THE PEOPLE OF VICKERSTOWN EACH SHOP IS CONFINED TO A DIFFERENT TRADE. THE COMBINED SHOP AND DWELLING HOUSE IS COMMODIOUS, CONSISTING, AS IT DOES, OF SHOP, STORE-ROOM, LIVING ROOM, AND KITCHEN ON THE GROUND FLOOR; AND SITTING ROOM, FIVE BED-ROOMS, AND A BATH ROOM ON THE FLOOR ABOVE

BY COURTESY OF IAS. C. FERGUSON, VICKERSTOWN

owners, encouraged no doubt by appreciation in value,—or unearned increment,—have sold their houses and thus the scheme is robbed of much of its distinctive characteristic and advantage. Messrs. Vickers further decided that no tenant could be accepted who was not recommended by his foreman as a diligent and conscientious worker. Recognising, too, that a man's home life directly influences his work the company arranged that the condition of the household must be maintained satisfactorily to ensure continuance of occupancy. Apart altogether from the financial advantages, residence in Vickerstown thus confers a cherished distinction. The population constitutes an aristocracy of labour, recruited from all ranks because the houses are of all sizes.

The conditions thus defined, the company entered upon their scheme quite four years ago. An admirable site was available on an island of 12,000 acres in extent, off Furness, in Lancashire. The island is separated from the works by the channel into which the ships when built are launched. This channel is spanned by a large steam ferry, which will soon give place to a bridge. The sea-washed shores of the

island afford healthy promenades and the undulating slopes and wide plains enable all forms of recreation to be indulged in. The construction of the town has been carried on under economical conditions as the result of the experience of the company and the financial resources available. The bricks for the houses are all manufactured on the estate, in works having a producing capacity of 50,000 bricks per day, and equipped with the best of mechanical appliances. Sand and gravel were also available and mortar-making machinery is employed. The houses were built without the interposition of middlemen, and at a very low first cost, so that the tenants gain in getting superior accommodation for a small rent. Houses have been built to suit all classes of workmen, the rents varying from 5s. to 9s. per week, including rates and taxes, with a few villas for draughtsmen and foremen. The cheapest dwellings have four apartments with the usual offices; but the great majority have six apartments with bath room, the rents in this case ranging about 7s. 6d. per week. It goes without saying that drainage has had special attention, the septic tank system has been adopted and the tanks are built under the ground level, and covered over to form two public gardens. The quaint gable decorations and mullioned windows of the houses recall the old Cheshire style, while internally all the rooms are finely decorated. Being lighted entirely by electricity the interiors are bright and attractive.

In this connection a word may be interjected as indicating that the parental government of municipalities is not always a blessing. The intention was to have a separate electric generating station for Vickerstown, or to take "current" from the Vickers works, where it is produced for about a halfpenny per Board of Trade unit, including all costs. This compares with illuminating gas at 6d. per 1000 cubic feet. The low cost is a result not only of high economy in production, but because the demand fluctuates only within narrow limits. There is, therefore, no need for machines running except when they are wanted, and in a working man's town it is possible to calculate within a few lamps the number which will be lighted at sunset and the number which will be kept running until bed-

ANOTHER BLOCK OF TYPICAL VICKERSTOWN COTTAGES

BY COURTESY OF JAS. C. FERGUSON, VICKERSTOWN

A COFFEE STAND IN VICKERSTOWN

time. In other districts populated by various classes of society the engineer of the electric light station never knows whether the occupant of a house with ten to forty lamps will have all these running or only one or two in the kitchen. Coal is burned and steam wasted to meet a large or even a full demand, although the actual requirements fluctuate very considerably. In Vickerstown it may be predicted that 1200 or 1500 lights will be run in the winter season from 4 to 11 P. M., and thus there would require to be no great surplus energy developed and little waste. This is a point not often remembered, but important in all working class districts, including "Garden Cities," as such regular demand makes a considerable difference on the cost of generating the electricity. The Vickerstown authorities, however, did not succeed in getting a station of their own, as the district, although separated by a wide channel from the main town, is within the borough of Barrow-in-Furness, which has its own municipal electric station.

The town is built on two heights separated by a valley which has been laid out as a public garden seven and a half acres in extent, with its sloping banks terraced with winding walks and parterres of flowers and shrubs. Centrally

situated is a band stand, where the works orchestra plays regularly. The northern town has its streets and avenues named after generals; while those in the southern part recall the names of famous ships built at the works. The lines of the principal streets are relieved by flower beds, and climbing plants grow on the walls of the houses, both being attended by the company's servants. The question of flower gardens to all houses was carefully considered as advocated by the promoters of garden cities. No one will gainsay the advantage of flower or vegetable cultivation as a recreation to workers in a great factory, but all men and all women are not sufficiently endowed with that natural love for horticulture which makes the work of tilling the soil and tending the plants a real pleasure; nor are they all disposed to pay for plants. It sometimes results that the appearance of such a district is soon anything but satisfactory. In Vickerstown such as have a desire to cultivate plants and vegetables can have garden allotments at normal rents; but so far as floral effects in the streets and terraces are concerned the company's gardeners attend to them; only in the better houses are there private front gardens.

The town has its shops, many of them on a co-operative principle, and Viscount Dunluce, who manages the estate, hopes in time to supply milk, dairy produce, and vegetable supplies from the agricultural land on the estate. Free sites have been granted for churches of all denominations and there are two schools. None of the inhabitants need have difficulty in disposing of leisure hours in a rational and profitable way. For open air recreation there are football and cricket grounds, bowling greens, golf links; the garden allotments extend to six acres. There is an institute for the encouragement of science study, and literary pursuits, and for enabling votaries of chess and other such games to exercise their skill.

The question of a public house required serious consideration, owing to the employers having to deal with men of independent habits of thought. The directors of the Vickers Company have evidently taken the view that they cannot interfere with the freedom of choice of educated and intelligent workers in this matter, and most will agree. At the same time they seek to influence the choice in a right direction. Colonel Vickers' daughter, Mrs. Parry, who, with Mrs. Vickers and Mrs. Albert Vickers, has taken a deep interest in this general scheme for improving the housing of the workmen and their families, is at the head of the Board of Directors of a public house on Lord Grey's Trust principle which offers a most satisfactory compromise. Curiously enough, much of the opposition came from the total abstinence party; but employers are not concerned with the action of the workmen outside of the works except so far as it influences the efficiency of their work. Intemperance in any habit must have this result. It may be that anything short of total abstinence from intoxicating drink may ultimately have such influence, but it is well to recognise that educated workmen resent prohibition in any form. They can, nevertheless, be influenced by example.

A man may thus enter a Trust house with temperate or total abstinence companions. The manager has no commission for selling intoxicating drinks, but has direct gain on the sale of other refreshments, so that it is not difficult to prophesy in which direction his effort will be exerted. Men who wish to have their tankard of beer or nip of whiskey may be satisfied in a public house on the Trust scheme, and still have around them continuous, although perhaps silent, influence operating in another direction, which may ultimately be completely effective, but must ever act as a restraint against excess.

If, on the other hand, there be no such combination of the two systems, the man accustomed to drink will refuse to be "coddled," as it is termed, and may induce companions to go elsewhere for their game of chess or billiards without any intention of seeing them cross the line. But no man cares to be exceptional; anyone, for instance, shrinks from entering a room where all are in evening

dress unless he also be similarly attired. A working man has even a greater objection to being so exceptional as to be conspicuous. He might not care to sit with others who were drinking whiskies and sodas while he partook of coffee, even if the landlord cared to encourage him. And for all these reasons the Vickers directors have probably acted wisely in deciding in favour of Lord Grey's system.

Thus in all its agencies the residents in Vickerstown will have a free choice, all their organisations will be administered by themselves,—an important element in maintaining the interest of the people. At the same time the scheme in all its ramifications is self-supporting, although the Vickers Company have liberally assisted as far as was possible within limits of sound economic principles, so that the town may offer the fullest attractions to ensure that relaxation and recreation which bring the contented and well balanced mind essential to efficiency in work.

Current Topics

It is now three years since we were promised in no qualified terms transatlantic wireless telegraphy. At intervals that may be said to have corresponded more or less with marked depression in the wireless stock market these promises have been repeated with increased emphasis; and in full page advertisements the public has, among other things, been informed as to the exact prospective earning capacity of each transatlantic wireless circuit, which earnings never fail to show a clear 10 per cent. profit annually on the entire capital stock of the company. These earnings, be it pointed out, are based on the possible earnings of a circuit working every hour of the year at a rate about equal to the best speed of the Atlantic cables, which is assuming a maximum of business to be handled which the Atlantic cables have not yet found forthcoming. Probably these cables are not operated to their full capacity more than five-sixths of the time, exclusive of Sundays. The comparison is also made with the cable service as if transatlantic wireless telegraphy were an accomplished fact, whereas not only is this not so, but there is probably not at present a single wireless telegraph circuit in any part of the world where the business offered for transmission is sufficient to keep it occupied every hour of the twenty-four at the rate of speed mentioned, nor is it likely that there is in operation to day anywhere a system of wireless telegraphy that can be relied on

to work without interruption twenty-four hours of the day,—all of which is said without desiring to detract in the slightest degree from the immense importance of wireless telegraphy in its proper sphere. But the foregoing facts profiteth the advertising and press agents of wireless telegraphy nothing. Their business is to facilitate the transmission of stock to the pockets of prospective investors, and indeed,—we trust the remark will not be considered unkind,—this appears to be the part of the business now being most energetically carried on by many of the promoters of wireless telegraphy.

THE rein which some of these gentlemen give to their imagination is well exemplified in one instance where an installation consisting of a flag pole, a wooden building of the dimensions of an automobile shed, containing a small oil engine, a dynamo machine and the other ordinary apparatus of a wireless outfit, are alluded to as "a magnificent station" at Blanktown. When, however, the short time that has elapsed since wireless telegraphy was introduced as a new art is considered, one wonders not so much that transatlantic wireless telegraphy is not yet an assured practical success, but that the art has already attained a degree of practicability whereby it is possible to communicate between passing vessels, and vessels and the shore, with fair regularity and precision. For these results unstinted credit should be given to the inventors of the various systems; and it is, perhaps, quite possible that if these inventors were allowed to pursue their preliminary investigations and experiments to a conclusion without undue pressure to show immediate practical results of some kind, the actual progress would have been even greater than it has been. Sooner or later the possibilities and limitations of this art will be better understood, at which time it will be assigned to the work for which it is preeminently adapted, and the brain-wearing attempts to show its adaptability to purposes which are already better performed by other methods will be abandoned.

THE utilisation of what formerly were considered waste products and the resurrection of materials from a used-up state to a new condition of serviceableness have in recent times been developed to such a degree of completeness that we are scarcely prepared to admit that anything is ever irrecoverably lost. In this respect we believe in the conservation of materials just as we have long been taught to believe in the law of conservation of energy. From a purely practical point of view, however, some things certainly may be so completely lost to further use that their loss may well be considered absolute, and one of these is the metal lost in the wear of railway rolling stock brasses. For the speculator in copper values, the promoter of a copper "corner," to use the broker's cant, the copper which has gone into railway brasses need have no terrors. It is not likely ever to be available again in full measure. It is dissipated so completely, in part at least, that its practical recovery is not likely to receive much serious consideration. From the best available deductions on the subject it appears that 5 per cent. of the annual copper production of the world disappears in this way every year.

IN summing up the various advantages of the steam turbine as a prime mover, we may very properly regard it as a machine which satisfies better than any other form of steam engine the conditions which, according to thermodynamic laws, make most fully for maximum economy. In fact, all the prominent defects of the normal steam engine are absent in the turbine. Theoretically it is much superior to the piston steam engine. The working fluid is always supplied at one,—and that the maximum,—temperature. It is always discharged at one,—and that the lowest,—temperature. The expansion is wholly

adiabatic. The loss due to friction over the surfaces of the guide blades and buckets reappears as heat. Yet, with all these favourable conditions, it is, as the London *Engineer* recently remarked in an article on "The Thermodynamics of the Steam Turbine," all that the turbine can do to compete with good piston engines. If the steam were used under the same conditions in the turbine as in the piston engine; if, for example, the supply of steam, instead of being constant, were intermittent, so that heat exchanges took place between the steam and the metallic surfaces, or if the back pressure amounted to even four pounds or five pounds, the turbine would be one of the worst possible engines, instead of being one of the best; and so the question arises, What is the reason that the result is not, in practice, much better than it is? Where is the heat energy wasted in the steam turbine? That great waste must go on is demonstrated at once by the fact that a machine which satisfies very fully all the conditions of thermodynamic excellence is scarcely as economically efficient as another heat engine which does not in any full sense of the word comply with these conditions. The question is one of some importance, and probably admits of several answers. One is that it is impossible to prevent some steam from passing through the turbine without doing work. If a turbine were blocked so that it could not revolve, and steam were turned on, there would be, of course, nothing to prevent a great deal of it from passing through the wheels. Just the same thing would happen with a water turbine, an overshot, or a breast wheel. In theory the water delivered through a turbine ought to have all the velocity taken out of it, and should merely fall away from the wheel. In the steam turbine the steam should behave in just the same way. It is, however, reasonable to believe that the "leakage,"—we cannot find a better word,—of steam through the turbine is so large that the piston engine being saved this loss, continues to remain at least as economical in fuel as its rival. It will thus be seen that there is room for improvement in the new engine. The thermodynamics are in every way favourable. Indeed, investigation points to the fact that the steam turbine ought to be the most economical steam engine it is possible to construct. The reasons why it is not, deserve very careful investigation. It may be taken as certain that they are not thermodynamic, at least in any ordinary sense of the word; and the fact ought to be encouraging to those who hold that so long as thermodynamic theory is complied with, all should be well. Fifteen pounds of steam per hour per brake horse-power may be taken as a fair average performance for a steam turbine. As the turbine cannot be indicated, its indicated horse-power cannot be ascertained. But it may be assumed that the friction of the machine is so small that its mechanical efficiency must be high, and, consequently, the indicated power is not very much in excess of the brake horse-power. Reasoning in this way, a good steam turbine will require about fourteen pounds of feed-water per indicated horse-power per hour.

THE introduction of blue-prints into the United States was not such a rapid process as the present universal adoption of this method of copying tracings might indicate. According to *The Engineering Record*, the first prints of this nature shown in the country were part of an exhibit in the Swiss section of the Centennial Exposition at Philadelphia in 1876, and it was stated by one of the gentlemen in charge of that exhibit that the process had but recently been introduced into Switzerland from Germany. Mr. Rudolph Hering was requested to prepare an article for the "Proceedings" of the American Society of Civil Engineers on the Swiss display, and came across these prints while engaged on this work. He obtained a copy of the formula for the solution, and after some trouble secured the ingredients and tried the process at his home; this was in 1876, and was probably the first case of blue-printing in the United

A GERMAN ALCOHOL AUTOMOBILE OMNIBUS

States. He sought to interest the city engineer of Philadelphia in the process, but the latter was of the opinion that the operations would be too sloppy. Then he showed some of his prints to Dr. Coleman Sellers, but that eminent engineer refused to see anything good in them. Workmen, he said, were so accustomed to working from drawings in black ink on white or brown paper that the attempt to introduce drawings with white lines on a blue background would be the cause of serious trouble.

ALCOHOL expositions are becoming the fashion. Following those held in very recent years, and referred to in these pages at those times, there will be one at Vienna, to begin on April 16, and to close on May 13, 1904. It is to give a comprehensive illustration of the present condition of the world's alcohol industry, with particular reference to the use of alcohol for technical purposes, though it is to embrace also other industries connected with products of fermentation,—these to include such establishments as breweries, distilleries, malt houses, starch works and others. Chiefly interesting among the groups of articles which are to be made the special objects of the exposition will be the machines and apparatus for the utilisation of alcohol for technical purposes, such as alcohol motors and locomobiles, and agricultural machinery that can be operated with alcohol; alcohol automobiles; and heating, cooking, and lighting apparatus using alcohol. The exhibition promises to be elaborate in character, and, in any event, interesting and instructive.

WHEN fatalities or damages seemingly attributable to electricity occur, the popular belief is that electricity itself, as a force, is directly responsible for them. In fact, however, there are few forces of nature that are less harmful in themselves than electricity. The damage done by flood or tornado, for instance, is done directly by the water or the air. But electricity, when it works, usually does so indirectly or by setting another of nature's forces into operation. An exception to this may be where the victim may have been so weak, physiologically, that a simple fall from a chair might have had a similar result. But in the majority of cases death from electric shock is shown to be due to well-defined chemical changes in the blood or tissues, due to the electric current. The damage done also to gas and water pipes by electrolysis, whilst primarily

occasioned, it is true, by the escape of electricity from electric railway circuits, is not directly due to that force, but rather to a secondary action, and that a purely chemical one, namely, the setting free by electrical action of certain elements, such as chlorine and sodium, constituents of a saline solution in the soil, which attack and corrode the iron pipes. Without some such solution in the soil there would be no such thing as electrolysis. Also, when lightning strikes a tree and shatters it, the result is not due directly to electricity, and not even to the electric current, but rather to the intense heat which the electric current generates in passing through the tree, which heat suddenly converts the sap into steam, and the latter in expanding, if the force be sufficient, tears the tree to pieces. If the force is not sufficiently powerful, the effect may be only to loosen the bark of the tree in places, the evidence of which may last for years, but may not be otherwise hurtful to the tree's growth. So far, indeed, from electricity being necessarily fatal to animal or vegetable life, it is well known that in proper quantities it is decidedly beneficial, and, when properly applied, acts as a stimulus to vegetation. An excess of current, however, will also kill vegetation. In both of these cases its action is due to the chemical changes which it effects in the growing plant or tree.

THE injuries to shade trees by contact with wires carrying heavy currents, such as electric light or traction wires, is mostly mechanical, an arc forming at the point of contact of the wire with the branch or limb and burning away the wood, leaving the tree stunted at such places. In very stormy, wet weather, it is not uncommon to have large trees set on fire by the escape of current from abutting electric light wires, the rain, paradoxical as it may seem, by improving the conductivity of the circuit down the tree to the earth, virtually adding fuel to the flames.

PIPE-LINE engineering, as to-day most popularly exemplified, perhaps, by the transmission of oil over long distances through pipes, has attained its highest and widest development in the United States, where the oil and natural gas industries combined have made heavy demands upon its capabilities. Commodities other than gas and oil have been, and are being, more or less successfully transported in similar manner, —coal, for example, in pulverised form mixed with a large proportion of water, to act as a carrying medium, and earthenware paste in potteries; but outside of gas and water works systems for city and town supply, which are really pipe-line engineering works, though not strictly in the sense of the term as commonly used, pipe-line transportation is confined almost entirely to oil and natural gas, as above mentioned. Some measure of the extent of the natural gas pipe-line industry is afforded by the recent statement in the *Engineering and Mining Journal* that there are in the United States something like 25,000 miles of such gas pipe-line. The pipe used is of various sizes, ranging from 2 inches in diameter up to 36 inches. The cost of laying a 6-inch line has averaged $4750 a mile. The pipe commonly used is wrought iron pipe, known as "line pipe," which is tested up to 1500 pounds pressure and is made with longer couplings than ordinary pipe. The standard sizes range from 2 inches to 12 inches in diameter. The smaller pipe lines, say 10 inches in diameter or less, are usually laid with the standard screw-joint line pipe, but lately plain-end pipe, with couplings and rubber packing, has become very popular, and is, to a large extent, taking the place of screw-joint pipe, it being equally cheap in first cost and more readily laid. The pipe line should be buried under ground, so that the distance from the surface of the ground to the top of the pipe will be 18 to 20 inches. This puts the line out of the way and makes it comparatively free from the expansive and contractive force to which it would be subject if it were exposed on the surface of the ground to the direct heat of the sun.

The pipe is protected with coal tar on the outside before laying. Expansion joints should be put in at about half-mile intervals, and also a certain number of gate valves and tees, to permit making connections at convenient points. A well-laid pipe line suffers comparatively little depreciation in value, and the pipe, after having been in the ground for four or five years, may be taken up and sold at a discount of only 15 to 25 per cent. from the first cost, according to the demand at the time. Second-hand pipe in large quantity is always more or less in request.

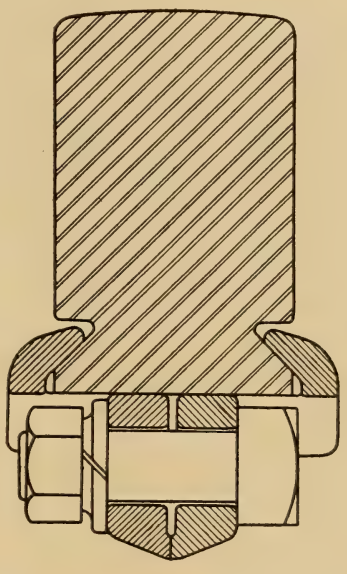
SIZES of pipe from 10 inches to 2 feet in diameter are frequently laid with what is known as the Converse joint. The pipe in that case has plain ends, the connections being made by heavy cast iron sleeves, or hubs, filled with molten lead which is calked into the space between the pipe and the sleeve. This joint has the disadvantage that the packing may be loosened by the settling of the pipe and the movement due to changes in temperature. However, by the addition of a rubber packing, pressed against the outside of the joint by means of iron clamps, a satisfactory connection can be made. Pipe lines of this construction have operated under a pressure of more than 300 pounds per square inch. For pipe lines of more than 2-foot diameter, cast iron water pipe or riveted steel pipe is put down. A line of riveted steel pipe of 36-inch diameter, extending 20 miles southward from Pittsburgh, Pa., cost approximately $50,000 per mile. At present, Pittsburgh is receiving gas from points in West Virginia more than 100 miles distant, while the lines which supply Chicago, Toledo and Cleveland are considerably longer, the gas in some cases being conducted 200 miles.

So much prominence has latterly been given to gas engines of large size that the motor of modest output, ranging, say, from 10 H. P. downward, has been completely overshadowed; and yet its use has been a steadily widening one, and this, too, in the face of electric motor competition which, at the outset, had by many been considered likely to be a crushing one. Available evidence points to the fact that in many places small steam engine and boiler combinations have been displaced by small gas and oil engines, the gas engines commanding favour even in localities with high-priced gas. In almost every instance the gas or oil engine has been found firmly established either by considerations of convenience, or of superior economy as compared with the small steam motor, or of both. In the marine field, for small pleasure boats, and even comparatively large ones, another outlet has been developed for motors of that type to a degree with which the steam launch engine has failed utterly to keep pace. Gasolene automobile engines are in a class by themselves, perhaps not rightly entitled to consideration here, though they, too, help materially to swell the volume of business in small motors of the internal combustion type.

A NEW conductor rail for electric railway service where the third-rail system is to be employed, recently designed by Mr. W. B. Potter, chief engineer of the railway department of the General Electric Company, of New York, has several good points to commend it, the best of all perhaps the simplicity of cross-section, which is essentially rectangular, as shown in the diagram opposite, with a dovetail arrangement at the bottom providing an easy means of securing the rail by fish-plates of special forms. Any of the usual kinds of bond may also be easily applied. The cost of such a rail, if ordered in, say, 1000-ton lots, should be little, if any, more than that of a plain rectangle of equal weight, and whatever wear may result will have a minimum effect on the area of cross-section, as compared with rail sections of the kind now used. The importance of this is very evident when it is borne in mind that the wear in the case of one of the

largest third-rail installations in existence is said to have amounted to about a tenth of an inch in depth of rail head in considerably less than a year's service. When 2½ inches wide and 4 inches high, Mr. Potter's rail will weigh about 98 pounds to the yard. The matter of contact rail wear from friction of the current-collecting shoe has naturally often suggested the query why some form of rolling instead of sliding contact device is not in use as with the overhead trolley wire construction; but this is at once disposed of by the consideration that with a roller collector and a third-rail conductor we could have, at best, only a line of contact which is not enough for satisfactory current transmission with steel as the transmitting material, the degree of electric conductivity of steel being, of course, much lower than that of copper,—approximately one-sixth of that of copper.

For the earliest third-rail installations, it was the custom to use old track rails when obtainable, and these were supplemented with new rails of standard T-section and chemical composition. With the coming of very heavy, high-speed service during the past few years, however, the resistance of these old and new rails alike was found to be so high that they would not carry the heavy currents necessary without too great a drop in the line potential. The rails would, therefore, have to be supplemented with additional copper feeders; but as this would be an expensive way to overcome the trouble, rails of higher specific electric conductivity were sought. Because of the lack of specific data on the relation between conductivity and composition of mild steels, specifications for conductor rails have usually been based on the fact that the conductivity of a metal is generally more or less directly in proportion to its purity. In most cases the purity of the iron specified for such rails has been so high that not only was it difficult to obtain, but the iron was also of correspondingly high price. One of the factors governing the choice between a third rail and a trolley wire is the relative price of steel and copper, allowance being made for the difference in conductivity. Hence, a balance must be struck between high conductivity (which is equivalent to saying a high degree of purity or freedom from the usual metalloids associated with iron) and the cost of producing the steel of the composition necessary for the conductivity required. With the object of drafting a rational specification for such third-rail steels, a series of tests was started last



CROSS SECTION OF A NEW CONDUCTOR RAIL FOR ELECTRIC RAILWAYS

spring in the testing laboratory of the General Electric Company on steels of as wide a range of composition as could be obtained from the steel makers, and the results of these tests formed the basis of a paper presented recently to the American Institute of Mining Engineers by Mr. J. A. Capp, under whose supervision the experiments were carried out.

The T-section of rail was the outcome of designs intended to present the greatest life and strength of the scetion, with the least weight of the metal, con-

ditions necessarily to be met in a running rail. But the conditions for the third or conductor rail are different; here, there must be provided sufficient surface for the collection of the current, and cross-section ample to carry the current without an undue drop in the line potential. The strength of the section is of little moment, and any section which is easily installed in an insulator is satisfactory. This permits the use of sections rectangular, or nearly so, which may be rolled easily in any mill equipped for the rolling of merchant-bar shapes of reasonably heavy weight, and it was with these facts in mind that Mr. Potter fixed upon the section shown on the preceding page. As to the chemical make-up of the most desirable kind of third rail, Mr. Capp concludes that the lowest possible resistance,—from six to six and one-half times that of copper,—is not necessary, and the relatively great cost of making steel of the required degree of purity for this is not warranted. In fact, such pure steels would probably be so soft that the frictional wear of the collecting shoe would be excessive and the life of the rail in service unduly short. Assuming, then, that a rail made from steel having a resistance not greater than eight times that of copper would be desirable for conductor rails, the figures obtained by Mr. Capp would seem to indicate that the analysis should be,—

	Per Cent
Carbon not to exceed	0.15
Manganese not to exceed	0.30
Phosphorus not to exceed	0.06
Sulphur not to exceed	0.06
Silicon not to exceed	0.05

Steel of this composition could be made easily in any open-hearth furnace, and it should present no difficulty in rolling to a shape suitable for conductor rails.

WIRE glass, as a protective material against fire spread from what are known as outside exposure hazards, was much recommended by Mr. P. M. Stewart in a recent paper before the International Association of Fire Engineers. In a closely built-up location, as Mr. Stewart pointed out, no matter how much care or money has been expended upon a building to make it safe against fire within itself, there still remains the danger of fire damage, if not destruction, from the outside. Fire underwriters generally regard a brick wall, increasing in thickness from the top down, as the most satisfactory protection against the attacks of fire from the outside. If a building could be enclosed in solid brick walls on all sides, carried 3 feet above the roof level, it would be practically safe against fire from the outside. But the public is not yet ready to sacrifice the space necessary for the interior courtyard that would be required for light and ventilation purposes under such conditions. Tables of fire loss, covering a number of years, show that nearly one-third of the fire loss of the country is due to the outside exposure hazard. Fire is communicated from one building to another in almost every case through wall openings,—through doors or windows,—and to provide against this danger, fire protectionists have devoted some of their best endeavours.

SINCE wall openings must normally be open more or less of the time, either to traffic or to the passage of light, the first form of protection took the obvious form of a sheet iron door or shutter arranged to be closed at night. Practical experience, however, soon showed that any considerable amount of heat warped the sheet iron shutter to such an extent as to seriously impair its usefulness. A great improvement on the iron shutter came with the design of the tin-clad wooden shutter, a device without a superior for many forms of wall opening protection. As applied to the window of mercantile establishments, however, the tin-clad shutter shared with the sheet iron shutter several defects. It did not permit seeing from the outside a night fire in a building; it did not lend itself readily to the adaption of devices to close the shutter automatically in the event of fire; and it was very unsightly. Here was the opportunity for the fireproof window, glazed with wire

glass, and set in a sash and window frame covered with metal. The wire glass is made either with an opaque or polished surface, and the wire reinforcing, embedded in the glass itself, although claimed to keep the window intact against the attack of a fire of almost any intensity, may be broken readily by the fireman when it becomes necessary to enter the building to introduce a fire stream. The efficiency of such wire glass windows in reducing the exposure hazard is said to have been well demonstrated in several recent important fires. In each of these instances the spread of fire to valuable property but a few yards distant is understood to have been prevented through the resistance offered by the window material in the walls of the adjoining building.

JUDGED from some of the things told in the latest annual report of Mr. Michael Longridge, chief engineer of the Engine and Boiler Insurance Company, of Manchester, the insurance of electric motors would seem to be a highly speculative business. Taking a general average, one dynamo in twelve has an accident during the year, whilst one motor in eight may be expected to break down. These are average figures, but in certain industries the "mortality," if one may use the term, is much higher, since, on the average of motors employed in collieries, one in three breaks down annually; whilst of those used in actual coal cutting, the casualty rate is as high as 50 per cent. Further, this class of machine suffers from general deterioration to a marked degree. In the case of motors, fully one-fourth the failures arise from old age. The insulation in many instances is found affected to such an extent that, if disturbed, it falls to pieces, and damage to a single conductor, therefore, involves the complete rewinding of the armature. Overloading, as a cause of failure, is apparently less common, but is still responsible for one-seventh of the total motor breakdowns. In one case a two horse-power motor, designed for a current of 17 ampères, was fitted with a "fuse" consisting of a length of No. 18 B. W. G. copper wire calculated to melt at 108 ampères. On test, it was found that the working current varied between 23 and 27 ampères, rising to 30 at starting. In a sister motor of the same size, the current at starting rose to 105 ampères. A curious accident noted is the fracture of the armature shaft of a small motor. The break started in a V-groove less than 1-16 inch deep, turned in the shaft to prevent the creeping of oil. The localisation of strain thus occasioned is an obvious source of weakness.

IN the matter of gas and oil engine breakdowns Mr. Longridge gives figures which show that a very large proportion of the failures arise from the negligence of the owners or attendants, a negligence which probably arises in the main from ignorance, and will be less in evidence as more experience is gained with this class of motor. On the other hand, the fact that only 12 per cent. of the accidents arose from bad design or workmanship is a feather in the cap of the makers of gas engines, since in the case of steam engines the proportion thus originating was nearly double this figure. With steam engines, as indicated by Mr. Longridge's tabulated statements, the valves and valve gearing retain their pre-eminence in the matter of causing trouble, and next to them come air pump buckets and valves. It is worth noting here that with gas and oil engines, too, valves and valve gears have been responsible for the highest proportion of failures, though trouble has also frequently arisen from jackets being burst through frost, and cylinders being cracked by overheating due to furring up of the water jackets for the cleaning of which no provision had been made. Returning to the consideration of steam engine ills it is to be observed that spur wheels, which at one time were a frequent source of dangerous accidents, are now much less in evidence, partly, no doubt, because very large spur wheels are now less used for driving

mill shafting than was the case up till recently. On the other hand, failures of steam chests and cylinder covers are becoming more and more common, and are, to a very large degree, attributable to the rise in steam pressures. In the case of one particular air pump breakage, in which the plunger was of the trunk type, Mr. Longridge remarks that nearly all trunk motions insured by his company have broken down at one time or another. The pin is generally inaccessible, dirt and grit accumulate at the bottom of the trunk, and wear takes place, which is followed by "knocking," and results ultimately in a complete breakdown. A good many accidents have arisen also from water getting into the cylinders of engines. Where much water enters, relief valves are useless, since they cannot be made large enough.

THE theory of the alcohol motor has been made the subject of an interesting contribution to a recent issue of the London *Engineer* by Captain C. C. Longridge, M. Inst. M. E., being in the nature of a review of an essay by Mr. G. Chauveau, entitled "Contribution à la Theorie du Moteur à Alcool," presented before the "Congrès des Applications de l'Alcool." It appears from this that in 1887 Messrs. Salanson and Debuchy established experimentally that, assuming equal initial pressures, the thermal efficiency increased with the decrease of temperature produced by the explosion. *A priori*, this law would appear erroneous, since the heat is the origin of the work, and by lowering the temperature, and, therefore, the heat, the work also should be reduced. The anomaly appears only in the case of an explosion motor, operating on what may be termed a superheated cycle. Under this condition, the best existing motors discharge their exhaust gases at about 400° C. (752° F.), whereas a temperature of about 100° C. (212° F.) should be ample. This latter figure would represent a reduction of 300° C. in the temperature cycle, and an improved efficiency, owing to reduced losses through the walls and circulating water. The cooler cycle, in fact, produces an equivalent result in work, because its heat losses are less. This conclusion, according to M. Chauveau, is in perfect agreement, not only with the law of Salanson and Debuchy, but the wall loss theory of M. A. Witz, and with the results of practice. The effect of compression, which, in explosion motors, should accompany this cooler cycle, is to raise only slightly the temperature, but largely to increase the pressure of explosion. Thus, the initial pressure point, from which expansion starts, is heightened, whilst the final point or terminus, to which it is carried, remains the same. Practically expansion is increased, and, therefore, efficiency. But there is another advantage,—high compression, by adding somewhat to the temperature, by bringing the molecules into closer contact, and reducing the volume, facilitates ignition and flame propagation, thus favouring rapid and perfect combustion, and increasing the proportion of heat converted to work. For the same reasons it permits the use of poorer mixtures,—another step towards economy and efficiency. An objection has been raised that, where liquid fuel is used, high compression leads to condensation. M. Chauveau, while admitting the fact of condensation in a cool vessel, denies its existence in the hot combustion chamber of an explosion motor, where the temperature is always far above the volatilisation point of the liquid.

THESE multiple advantages of the combined cool cycle and high compression are characteristics of the alcohol motor. The reason is evident. For any particular mixture, the limit of compression, apart from constructional considerations, is fixed by the risk of automatic ignition or unduly violent explosion. It is here where the beneficial influence of alcohol appears. The water it contains absorbs heat during compression, and thus, lowering the temperature, enables the compression to be raised without risk of charge ignition.

This effect, visible wherever alcohol is used, naturally varies according to the proportion of water present. But, according to M. Chauveau, if this reasoning is true of alcohol, it should also apply to any other explosive mixture. In other words, any explosive mixture, if hydrated, should give better results than if unwatered. Petrol, in particular, should follow this law. Alcohol, in fact, is merely a hydrated hydrocarbon; and hydrated petrol,—a sort of artificial alcohol,—should impart to the motor in which it is used the characteristics of the alcohol motor. This, affirms M. Chauveau, is the case, and he adduces in proof the instance of the Banki motor, exhibited by Messrs. Ganz & Co., of Buda Pesth, at Vincennes in 1900. The distinctive feature of this motor is the injection of pulverised water into the cylinder during compression. But what the more complicated mechanical addition of water to petrol does for this engine, that the mere alcohol, by its own composition, does, in a simpler way, for the alcohol motor. M. Chauveau concludes his study with the enunciation of three laws: 1.—The thermal efficiency of internal combustion engines, under identical conditions, is so much better, as the internal cycle is cooler, owing to the lesser wall losses and the higher compression obtainable. 2.—A cool cycle can be obtained with any combustible mixture, provided water, in suitable proportion and form, is present in the cylinder before compression. 3.—The alcohol motor, by reason of its hydrated fuel, runs with a cool cycle, and, therefore, greater efficiency than the petrol motor.

ALEXANDER CROMBIE HUMPHREYS

President of Stevens Institute of Technology

A BIOGRAPHICAL SKETCH

THAT the engineer should be a business man, or at least conversant with business conditions and methods, has been the leading principle in Dr. Alexander Crombie Humphreys' just opening career as an engineering educator, and Stevens Institute of Technology, at Hoboken, N. J., of which he became president last year, will thus profit largely by the infusion of a healthy business spirit in all its departments.

The selection of Dr. Humphreys to succeed the late Dr. Henry Morton as the head of the above institution was a peculiarly fitting one. Dr. Humphreys himself graduated at Stevens in the early eighties under special conditions, to be referred to later, and in the succeeding twenty odd years achieved distinctive success in practical engineering work both as chief engineer and general manager of what is probably the largest gas engineering company in existence, and as senior member also of the firm of Humphreys & Glasgow, who have done much, both here and abroad, in bringing gas works practice to a high plane of excellence.

Labouring thus, Dr. Humphreys had full opportunity to discover and appreciate the needs of the young engineer in practical life, and when he entered his new field of work as a college president he took with him the vital atmosphere of the workshop and business office, and this has since then been the atmosphere at Stevens. In this respect Dr. Humphreys splendidly exemplifies the correct modern idea of what an engineering college professor should be,—not the development of the musty class and lecture room towards which there is still an unfortunate leaning,—

but the man of affairs in the engineering business world, the man who has made contracts as well as plans and specifications, who knows what things will cost as well as what they will do, and who has wrestled with the many problems which come constantly into the battles of everyday engineering work.

Dr. Humphreys is Scotch by birth, having been born at Edinburgh in 1851. His father was Edward R. Humphreys, M. D., LL. D., a well-known classical scholar and educator; and his mother was Margaret MacNutt, of Prince Edward Island, Canada. In 1859 the family moved to Boston, and at the age of fourteen young Humphreys secured an appointment to the United States Naval Academy, passing the preliminary test examination. It then developed that he was under the required age for entrance, and he was, therefore, debarred by the authorities. It being necessary that he should do something for his own support, he found a position in an insurance company. Two years later this company failed, and he secured a position with the New York Guaranty and Indemnity Company, now the Guaranty Trust Company.

With this company he remained until 1872, by which time he had risen from office boy to receiving teller and assistant general bookkeeper.

For years he spent much of his spare time working with tools, and since 1871 he had been brought into contact with things practical through acting as secretary to the building committee of the Bayonne & Greenville Gas Light Company. Upon the completion of this company's works, in 1872, he was offered by its board the position of secretary and treasurer, which he accepted. A year later he was also made superintendent.

After toiling for five years at the underlying drudgery of the business he perceived that he was not justifying the hope of notable success in his work. Having convinced himself of what he considered his unfitness for his occupation, he did not cast about for more congenial and promising employment, but straightway grappled with himself. It was not his work, but himself, that aroused his dissatisfaction. He felt the will to wring success out of existing circumstances, and looked to increase his forces rather than smooth his path.

His deliberate conclusion was that he needed special technical education in order to raise his work to a satisfying plane. His rare powers of analysis, which subsequent experience ripened into his present judicial poise, were even then focused upon himself as dispassionately as they were applied to exterior relations. Even at that time Dr. Humphreys showed the ability to measure himself against opposition, and fortify himself accordingly with the energy and resolution to act upon his conclusions.

His characteristic self-confidence is but the logical result of this power of adjusting force to counterforce. Having reached this conclusion, as an accountant arrives at his balance, he was not long in making new and radical dispositions.

His attention having been directed to Stevens Institute, he presented his case fully to the president, the late Dr. Henry Morton, and finally obtained permission to follow the full regular course while absenting himself from all recitations and lectures, except those he could cover in two mornings of each week, provided he would attend all reviews and all examinations, and would arrange to do outside of the Institute all the prescribed work not covered in the hours of attendance. Under these conditions President Morton thought it might be possible to complete the four-years' course in six years, but he did not hold out much hope.

Humphreys had left school at the age of fourteen, twelve years previously. He was without the habit of study and utterly unqualified to pass the entrance examinations of the Institute. A year spent in preparation, however, enabled him to successfully pass the examinations, and, in 1877, at the age of twenty-six, he commenced study with the class of 1881. During the next four years he attended to his duties in the gas company and kept up with his class at the

Institute, graduating in 1881, at the age of thirty.

He thus compressed into his few "spare moments" the work which normal students, fresh from advanced schooling, accomplished only by four years of unremitting application. The president and faculty of the Institute passed a formal resolution congratulating him upon his success in graduating with honours under such exceptional conditions.

It is not out of place here to mention the generous confidence of Humphreys' employers, who granted him a leave of absence for the necessary two mornings weekly, although realising that such action must ultimately result in the loss of his services. Indeed, such was the case, for shortly after his graduation Humphreys became chief engineer of the Pintsch Lighting Company, of New York.

In this position, which he held for over three years, he built many oil gas works, acquired great experience in the manufacture and utilisation of gases of high illuminating power, and ascertained the gas-making values of all kinds of oil, especially with reference to the compression and storage of gas for the lighting of railway trains, ferry-boats and light-buoys. To this end he conducted much experimental and demonstrative work, and greatly broadened his previous knowledge of the gas industry.

In 1885 Dr. Humphreys was appointed superintendent of construction for the United Gas Improvement Company and shortly afterward general superintendent, with headquarters in Philadelphia. During Dr. Humphreys' decade with the United Gas Improvement Company the increase in his responsibilities more than kept pace with the marvellous growth of the company. He was first constructing engineer, next general superintendent, then he annexed the contracting department, then the purchasing agent's department, and finally the commercial management of all of the company's works.

Under the uniform system developed by Dr. Humphreys the parent company's many properties were operated from Philadelphia, and by constant comparison of results the experience gained at one property was applied for the benefit of all. In addition, he was acting general manager of the Welsbach Incandescent Gas Company, controlled by the United Gas Improvement Company, while its independent organisation was being effected. During this time the number of gas works comprised in the latter company's system increased from ten to nearly forty.

In May, 1892, the firm of Humphreys & Glasgow, of London, was established; and in August, 1894, Dr. Humphreys retired from his official connection with the United Gas Improvement Company in order to establish the firm of Humphreys & Glasgow, of New York, and the two firms together, notwithstanding their relatively short period of existence, have done a very large amount of splendid work along the lines of advanced gas engineering.

When, in the early part of last year, the presidential chair of Stevens Institute became vacant through the much-lamented death of Dr. Henry Morton, Humphreys at the very outset was mentioned for the office. He was not only generally considered to have all the desired qualifications for this important trust, but he was also the Institute's most distinguished graduate, and in conferring upon him the honour of the presidential appointment the Institute, after all, was but honouring itself. It remained then for Dr. Humphreys to be prevailed upon to sacrifice various other interests so that he might properly devote himself to the new educational ones, and with this part of the problem satisfactorily disposed of, the new régime at Stevens began practically with the beginning of the college year in the autumn of 1902.

Mr. Arthur Glasgow, Dr. Humphreys' business associate, and himself a Stevens man, in speaking of the appointment at the time and of the advantages which accrue to the Institute through the new president, remarked:—

"Obstacles must be stubborn indeed to withstand his vitality and resolution, while his judicial mind, with its search-

ing powers of concentration, will suffer no straying after false gods. He combines the most rugged qualities of action and progress with the tenderest human sympathies. His splendid self-confidence is not that born merely of success, which, when fortune changes, proves too often but a species of mental intoxication; but it is based upon habitual judgment from a comprehensive perspective, disclosing all influencing circumstances in their relative values.

"His personality must lend new life to a field unploughed by such forces, for not before has technical education been directed by so unique a blend of broad technical attainment, rare executive ability and experience, and that comprehensive grasp of practical affairs which alone unites cause and effect with a true sense of proportion, and conserves to maximum usefulness the energies within its sphere of influence.

"Since 1891 Mr. Humphreys has been a prominent trustee of then Institute. He is past-president of the Alumni Association, and has founded a scholarship. He initiated the course in business methods and bookkeeping, and has lectured to the undergraduates and addressed the graduating class. As president, therefore, he is an old friend in a new and more potent guise, and his heart is in the work."

Early in 1903 President Humphreys received from the University of Pennsylvania the honourary degree of Doctor of Science, and, in June, from Columbia University the honourary degree of Doctor of Laws.

PHOTO BY JOHNSTONE, HARTFORD, CONN.

Francis B. Allen

SECOND VICE-PRESIDENT OF THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE COMPANY

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THE CHAMONIX ELECTRIC RAILWAY

WATER-POWER AND PROTECTED THIRD-RAIL CURRENT SUPPLY

By Archibald Wilson

PREVIOUS to 1901 the tourist, en route for Chamonix from the direction of Geneva, had, of necessity, to perform the last stage of the journey by diligence. Cluses was then the terminus of the Paris-Lyons-Mediterranean Company's steam line, and from there a drive of twenty-seven miles through the wild valley of the Arve brought the traveller to his destination. Lying, as it does, under the shadow of the great Mont Blanc range, Chamonix has a world-wide reputation as the centre of some of the loveliest of mountain scenery and as a convenient starting point for numerous Alpine ascents, and its ever-increasing popularity made its connection with the railway system of France merely a question of time.

By July, 1901, the ordinary steam railway had been extended a further distance of seventeen miles to the small town of Le Fayet, and from that point to Chamonix the electric railway which is the subject of this article was opened for traffic. The line is a comparatively short one, being at present slightly under twelve miles in length from terminus to terminus, and is provided with four intermediate stations. Of these Chedde is next to Le Fayet-St. Gervais, then come Servoz, Les Houches, and finally, about two and one-quarter miles from Chamonix, the station of Les Bossons, situated at the foot of the famous glacier of the same name. As the difference in level between Le Fayet and Chamonix is about 1500 feet, the gradients are in some parts steep. The heaviest are, one of 9 per cent. between Chedde and Servoz, extending over a distance of 2300 yards, and one of 8 per cent. between Servoz and Les Houches, 1500 yards in length, while inclines of 2 per cent. are frequent.

For the first two miles the line runs through a comparatively level and open valley to Chedde, shortly beyond which the heavy climb begins. Beyond Servoz the valley of the Arve, which there narrows into a wild and precipitous gorge, affords ample scope for the ingenuity of

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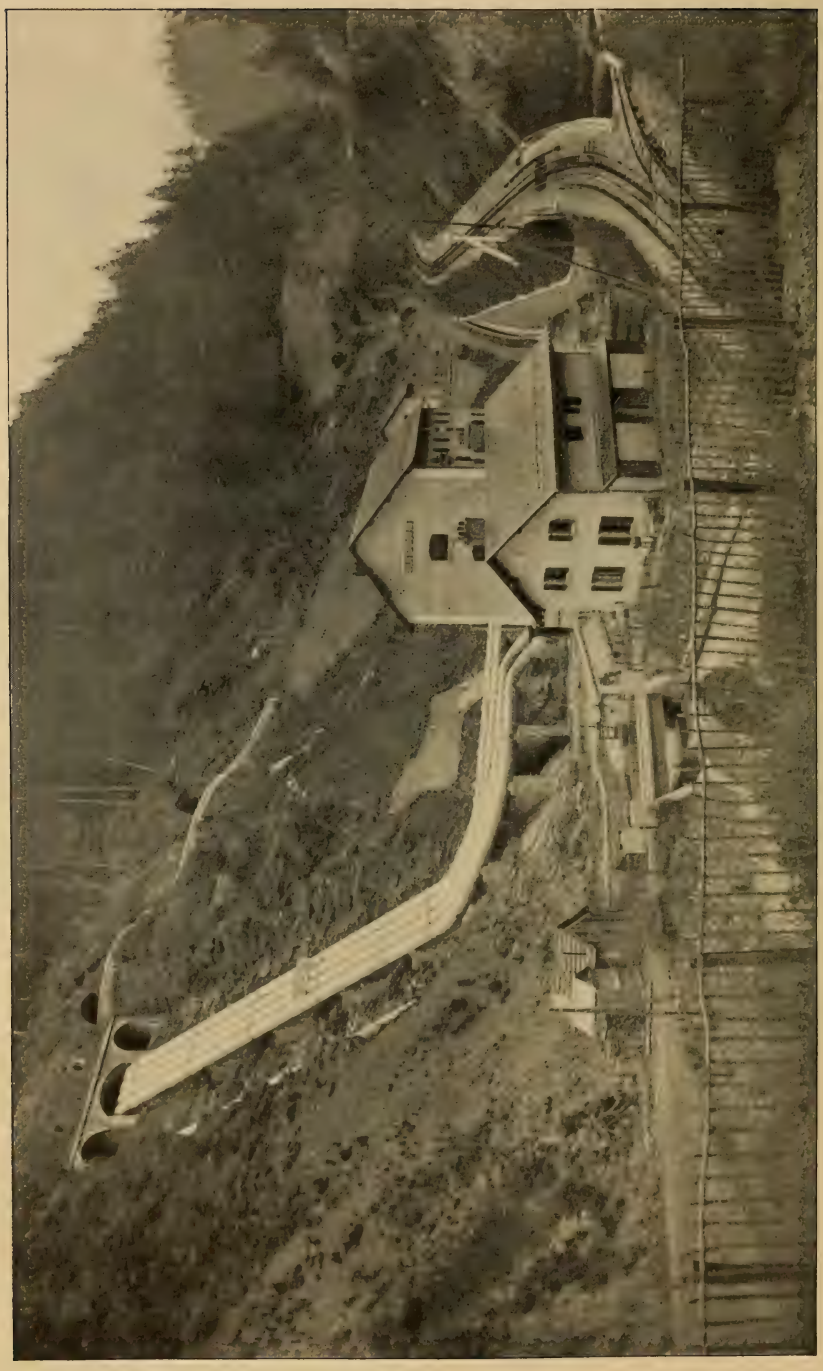


THE POWER STATION NEAR SERVOZ. A SECOND STATION AT CHAVANT, ABOUT THREE MILES DISTANT, IS SIMILAR IN LAY-OUT AND CAPACITY

THE FRONT LUGGAGE VAN, WITH THE DRIVER'S COMPARTMENT

the engineer in the necessity for deep rock cuttings, tunnels, and high embankments. Incidentally, it may here be mentioned that at a short distance from Servoz station there may be seen at the entrance of a rock gallery through which the high road has been driven, an interesting example of tunnelling by the Romans. The mouth of the tunnel is approached by steps cut in the rock at the side of the road, and is furnished with a signboard which informs the traveller that the ancient tunnel was discovered while blasting out the rock of the modern tunnel for the construction of the highroad about the middle of the last century.

At the head of the gorge the line crosses the Arve by a lofty masonry bridge, after which it ascends by easy gradients along the more open Chamonix valley through the stations of Les Houches and Les Bossons to its terminus.

From a picturesque point of view the railway can hardly be surpassed, the sight of the turbulent glacier waters of the Arve rushing through its gorge as the train winds its way high above the stream being varied by exquisite glimpses of snow-clad mountains and the rocky pinnacles of the Aiguilles, till finally, as the train emerges into the valley of Chamonix, there bursts into view the entire range of Mont Blanc with its snowy summits and glacier-covered sides.

As a natural sequence to the line being projected through a country lavishly provided with streams of rapid descent, water-power has been employed as the source of energy for the propulsion of the trains. Two power stations have been erected, one a short distance below Servoz, about four and one-half miles from the Le Fayet end, and the other at Chavants, two and three-quarter miles further up the valley. The general appearance of No. 1 Station at Servoz can be gathered from the illustration on the opposite page. The power house measures 100 feet by 40 feet, and consists of a basement through which are brought the inlet and discharge pipes of the turbines, and a first floor containing the turbines, dynamos, and switchboards.

The water is led from the river through tunnels and riveted steel pipes according to circumstances, and is delivered to the turbines at a pressure corresponding to a head of 130 feet. The machinery consists of four main turbines with horizontal shafts direct connected to the generators which supply current to the line, and two smaller turbines and dynamos which are used for the

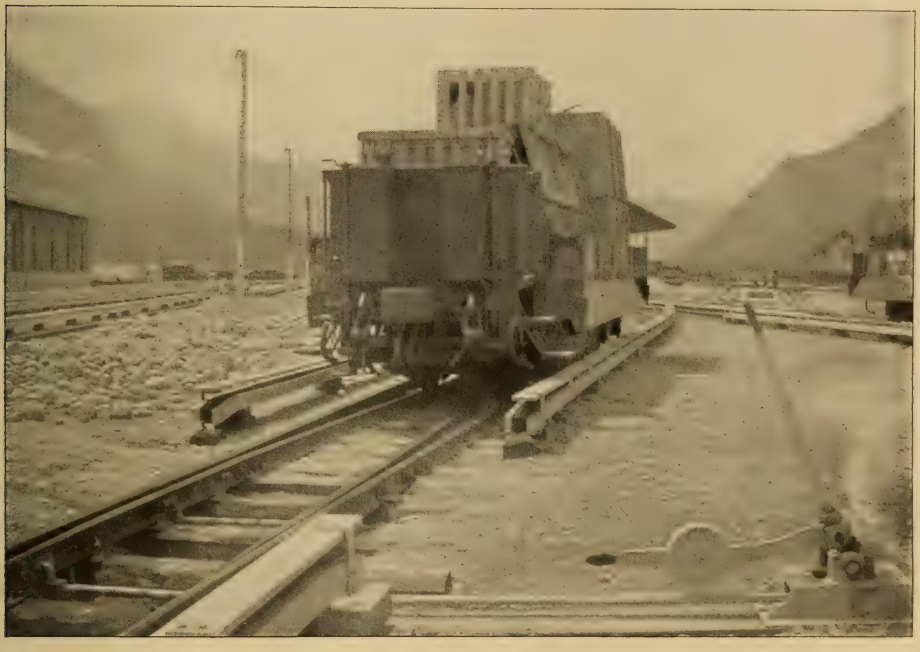
A VIEW ALONG THE PIPE LINE. SOME OF THE OVERHEAD FEED WIRES CAN HERE ALSO BE SEEN

lighting of the station and its adjuncts. The large turbines have a maximum capacity each of 350 horse-power.

The dynamos at No. 1 Station give out 550 volts at their terminals at no load with a speed of 615 revolutions per minute. With a speed of about 450 revolutions and a load of 440 ampères the pressure is 522 volts. The normal output of each generator is 370 ampères for continuous running; 450 ampères may be taken off for half an hour at a time; and for momentary periods of overload the current may run as high as 600 ampères, at which figure the automatic cutouts at the switchboard act. The exciter sets are designed to work at 120 volts with a maximum of 330 ampères, and their turbines are provided with governors maintaining the speed constant with all loads at about 520 revolutions per minute. No. 2 Station at Chavants, while differing slightly in detail, is equipped generally on lines similar to the station at Servoz. The head of water in this case is about 300 feet.

Current is conveyed to the motors of the trains by means of a third contact rail laid outside and parallel to the ordinary running rails. This third rail, which weighs slightly under 75 pounds per yard, is placed on one side or the other of the line according to necessity, at a distance of about 42 inches from the centre of the line and with its crown 9 inches above the top of the running rails. It is fixed with iron bolts to insulating blocks of paraffined beech, which, in turn, are bolted to oak distance pieces fixed on the ends of the sleepers. It might naturally be suggested that such a support did not possess sufficiently high insulating qualities having regard to the pressure employed, and that the leakage from the line would be considerable. Apparently, however, this is not the case, for the maximum leakage to earth is stated at less than one ampère per 1000 yards.

Moreover, it is also asserted that this leakage decreases with a fall of rain or snow. The reason given for this somewhat unusual state of matters is that



THE ARRANGEMENT OF THE CONDUCTOR RAILS AT A SWITCH

SEEN FROM THE TRAIN

dust, which has accumulated on the surface of the insulating blocks and caused leakage, is washed away by the action of the rain, while the water itself in the Chamonix district is so pure and free from acids or alkalies that its conductivity is practically nil. In consequence, after rain the insulation of the wood blocks is, on the whole, greater than before.

In addition to having fish-plates of standard pattern, the adjoining ends of the third rails are connected by two stranded copper bonds soldered to cast iron terminal plates which are bolted to the web of the rail. The running rails are bonded in similar fashion, but with only a single bond per joint.

To allow of the passage of vehicles at grade crossings, and also at switches, a gap is left in the contact rail, the interval being bridged by a copper

bond laid underground in a wooden trough run up solid with asphalt. At all such interruptions the rails are so disposed that at no time are the collector shoes on the vehicles entirely out of contact with the rail, and no interruption of the current to the motors, therefore, takes place. In the stations and other such places where the public may have access to the line, the contact rail is protected by a guard plank in such a way as to prevent accidental contact and still allow of the passage of the shoes. Elsewhere the rail is without protection of any sort. The disposition of the rail guard is very well shown in the illustrations on pages 203 and 206.

All the vehicles at present in service on the railway are equipped with motors and comprise eight different types, namely, front baggage vans, first-class carriages, second-class carriages, combined first and second-class carriages, and three types of goods waggons.

Each motor truck has two axles with 36-inch wheels, and each axle is driven independently by an electric motor. The motors are designed to run at a speed of 275 revolutions per minute, and are individually capable of working at the rate of 65 horse-power during a continuous run of two hours without excessive rise of temperature, while for short periods double this power can be obtained from them.

Owing to the narrow gauge of the line,—one metre,—the space inside the truck frame is somewhat restricted, and in consequence the motor shaft is placed at right angles to the axles, necessitating the use of bevel gearing. The gear wheels are of steel with machine-cut teeth, and work in a bath of oil. The larger of the two gears is mounted on the axle, to which it is attached by a flexible spring coupling provided for the purpose of lessening vibration and the effect of sudden strains on the armature. The motor frame is pivoted at the driving end on two arms which embrace the axle, while the other end is supported on springs attached to the truck frame. In this way, while the motor has a flexible support and is free to move to a limited extent, the exact relative positions of the gear wheels to one another are always maintained.

To make contact with the third rail,

SOME OF THE GOODS WAGGONS

THE WAY IN WHICH THE CONDUCTOR RAIL IS GUARDED AGAINST ACCIDENTAL CONTACT IS HERE CLEARLY SHOWN

each truck is provided with four collector shoes, two being fitted on each side. The shoes are supported on a system of hinged joints, and are pressed downwards by springs so that they follow any inequality in the height of the rail and always make good contact with it. The brackets to which the shoes are attached are bolted to the extreme ends of the truck frame, but are, of course, insulated from the frame.

For starting, stopping, reversing, and varying the speed, each vehicle is provided with a controller, the handle of which can occupy any one of eleven different positions. Of these the centre one is the "off" position, five are used for going forward, and the other five for reversing. Of the five working positions three are employed in starting, the fourth for running at normal speed, and on the fifth a higher speed can be obtained by reducing the excitation of the motor fields.

Each vehicle can be controlled independently by hand by means of a removable crank applied to the controller, but such a method is rarely employed except in shunting operations. When, as is usually the case, a train of from four to six vehicles is being run, the controllers in all the vehicles are worked simultaneously by compressed air motors whose action is regulated solely from a driving cab fitted in the front of the luggage van at the head of the train. For this purpose an air motor is fitted on the truck frame beneath each electric controller. These air motors are coupled to, and set in motion by, a master air controller fitted in the cab, so that to place the electric controllers on each vehicle in any desired position the driver has simply to move a hand wheel to the right or left, when each air motor moves its controller over to a corresponding degree. Accordingly, the control of a train is as easily and quickly effected as that of a single vehicle.

Power for working the compressed air controlling gear and also for the brakes is derived from a motor-driven air compressor in the luggage compartment behind the driver. In addition to the master controller, there is fitted in the cab various other apparatus required for working the train, including a connection box and automatic cutout for the

ONE OF THE FIRST-CLASS CARRIAGES. AN ELECTRIC CONTACT SHOE CAN BE SEEN AT THE RIGHT OF THE CONDUCTOR RAIL SECTION

motors, the latter set to open the circuit at 400 ampères, an ammeter, a speed indicator, switch gear for the compressor motor and for the lighting and heating circuits of the train, hand and air brake levers, and a whistle, also worked by compressed air. On the roof are fitted air reservoirs, while beneath the floor of the cab, and also of the various other vehicles, are suspended the air motors and the starting resistances.

The brakes, as has been mentioned, may be worked by hand or by compressed air, and are of two types. For ordinary service, each wheel is provided with a shoe brake acting on the rim in the customary manner. For additional safety a double-jaw brake is provided which grips the sides of a rail fixed in the centre of the permanent way slightly above the level of the running rails. This brake-rail is laid down only on the heavy grades. Under ordinary conditions the wheel brakes only are used, the jaw brakes being reserved for emergencies or in case of prolonged stoppage. In the illustration of the power station on page 200 the brake-rail can be seen in the centre of the line.

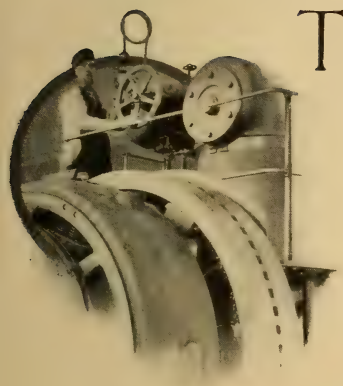
The seats of the carriages are disposed at right angles to the length, with a passage down the middle. The lighting is by means of incandescent electric lamps and the heating by electric radiators underneath the seats. Sitting accommodation is provided for twenty-four first-class passengers in each carriage, while the second-class carriages have seats for twenty-eight persons. In addition, at each end of the carriages of both classes a covered platform affords standing room for four persons. The windows are excellently arranged, providing ample ventilation and an uninterrupted view of the scenery. Each passenger carriage weighs about 19 tons when empty.

The goods waggons have a platform at one end only, on which are mounted the controller, an automatic cutout and the hand-brake levers. In other respects their construction is not very different from that of the goods waggons of an ordinary steam railway. The weight of a goods waggon when empty ranges from 18 to 20 tons, according to the type, while the carrying capacity of all three types is about 10 tons. The tare of the waggons is thus high in proportion to the load carried; but this is due to the fact that each waggon has its own motors, and is in consequence an independent unit, capable, if need be, of making a journey unassisted and of performing its own shunting.

The speed which the trains attain on the level is at the rate of about 25 miles an hour; when ascending a 2 per cent. incline, 15½ miles; and on the heaviest inclines of 8 and 9 per cent., 8 miles.

THE COMMERCIAL SIDE OF ENGINEERING

By Walter M. McFarland



THE question of how much a machine, or structure, or engineering work will cost, and whether it will pay, is almost always the one which decides whether it will be undertaken or not. Important as this point may be, it is often neglected by engineers of the very highest ability, so that among well-informed professional men it is very common to hear it said that the works of certain engineers are always sure to be the very best, but that they need a gold mine back of them to pay for the designs.

One often hears people say, laughingly,—"the best is good enough for us"; but it may be questioned very seriously whether in engineering we might not, with reasonable limitations, reverse this and say that "good enough is best."

As illustrating this last point, a monumental example was the great Ferris wheel at the Chicago Exposition in 1893. The particular point is with respect to the way in which the wheel was driven. The wheel was about 250 feet in diameter, and an ideal way to have driven it would have been by a worm, which would have made the motion absolutely smooth; but the cost of cutting worm teeth on such a huge wheel would have been absolutely prohibitive. Another method would have been by a wire-rope drive with a drum on the shaft; but this latter was about 150 feet up in the air, and if the rope had chanced to break the unfortunate passengers would have had to stay in the cars until repairs could be made.

Mr. Ferris devised a very much simpler plan, which many may have considered extremely rough; he made the device a huge sprocket wheel by notching the rim when it was cast, and it was driven by a sprocket chain down on the ground, where the parts could be constantly watched and inspected, and if anything did go wrong, repair could be made almost immediately. As a matter of fact, it is believed that there was never any accident to the driving gear and that people were never troubled by having to remain in the cars.

Several years later another wheel, even larger than the one at Chicago,—about 300 feet in diameter,—was set up at Earl's Court, in London. The engineers did not believe that "good enough is best," but put in a wire-rope drive. The rope broke on several occasions, and people were compelled to remain in the cars from twelve to sixteen hours. To the writer, Ferris' engineering appears first-class; it accomplished the object satisfactorily and cheaply, and was an entire success.

Another instance of what may be considered commercial considerations as affecting pure engineering was in the case of the machinery of naval vessels during the American Civil War. Mr. Isherwood, who was then engineer-in-chief of the United States Navy, was one of the greatest engineers whom America has ever produced, and was, indeed, a leader in the scientific appreciation of the true thermodynamic conditions connected with steam engines. He appreciated very much better than almost anyone else at that time the economic limitations of expansion, so that the action he took with respect to the engines he built was with full knowl-

edge of what he was doing. The engines which he turned out were extremely heavy, and have been criticised at times by ordinary designers for this supposed defect, as well as for the use of only a very moderate range of expansion. The engines were made heavy because the increase of the Navy created such a demand for engineers that it was impossible to supply an adequate number with thorough training, the consequence being that the machinery often went into the hands of quite unskilled people. Far more important than any question of weight was the vital one of being certain that the machinery would not break down. This was why the engines were made so very heavy, and, as a matter of fact, they did not break down.

The reason for using only a very moderate degree of expansion was to secure simplicity of valve gear; a higher ratio of expansion also would have meant very much larger and heavier machinery. It required a good deal of courage on the part of an engineer to go counter to prevailing views and general ideas, but Isherwood's machinery admirably filled the purpose for which it was designed.

Another illustration of the effect of commercial considerations on engineering design is shown by a comparison of the application of forced draught for boilers in war vessels and in merchantmen. In the former the full power involving maximum forced draught is used only occasionally, perhaps not 1 per cent. of the time the machinery is in operation, while in the merchant service the engines are used at full power almost the entire time. In war vessels weight and space are extremely precious, so that questions of economy receive minor consideration. The result is that in war vessels both engines and boilers are designed for good economy at about full power under natural draught, the consequence being that the boilers, as well as the engines, are too small for economy under forced draught. This is thoroughly appreciated by the designers, but to provide engines and boilers which would give high economy under forced draught conditions would necessitate probably 25 per cent. more space and weight, which are simply inadmissible; and, further, the machinery would then be so large that it would be very uneconomical at cruising speeds.

In the merchant vessel, as the conditions are uniform and full power is demanded all the time, both engines and boilers are designed for maximum economy under these conditions, and as weight and space are not so precious there as in the war vessel, the proportions can be readily made adequate to the desired result.

The effect of commercial conditions is also seen by comparing the Atlantic express steamers with cargo steamers for very long voyages, such as from England to China and Australia. In the express steamers very high speed is demanded by the travelling public, who are prepared to pay for it, so that while a fair degree of economy is desired and obtained, it would not pay to go to the complication which is reasonable for the long-distance service at slow speed. As showing what is necessary to get these extreme economies, reference may be made to the steamers *Inchdune* and *Inchmarlo*, which have given a horse-power for slightly less than one pound of coal. These vessels used superheated steam, a tremendous ratio of heating to grate surface in the boilers, and numerous appliances necessary for the utmost economy, but these made the machinery very heavy and bulky for the power developed. As the total horse-power of these vessels was not very great, it was practicable to resort to these measures, particularly as the increased space and weight for the machinery would be compensated for by the reduction in bunker capacity needed for the very long trips which they make. In the case of the Atlantic express steamers, however, whose trips between terminal ports do not exceed a week, and where coal is abundant and cheap at both ends, it would not be good commercial engineering to adopt all these economical appliances with the attendant complication and possibility of derangement, be-

cause in these vessels high speed and absolutely reliable passages are more important than economy.

One does not hear quite so much about it now, but from ten to twenty years ago American railway practice was much derided by British engineers. The roadbeds, bridges, and rolling stock were all said to be absurd, and the splendid stone bridges and finely ballasted roadbeds of the British railways, and their locomotives which would, with care, run forever, were held up as examples to follow. Anyone, however, with an open mind, and especially if he believed that the motto "good enough is best" was worthy of some faith, would have seen at once that there was a tremendous difference in the circumstances surrounding the two cases. In Great Britain there were short distances and a dense population, and wood was relatively expensive. America was a country of magnificent distances, a sparse population everywhere, and an exceedingly scanty one in many places, and with a superabundant supply of wood. If the railways were to pay at all, they must be built cheaply and with low-priced materials. Hence, the rough track equipments and the wooden bridges. As time has gone on and the country has become more thickly settled, and the price of steel has enormously decreased, we find very much better roadbeds and steel bridges taking the place of wooden ones, while in some cases stone bridges are also used.

With respect to the locomotives, American engineers are not yet willing to admit that the British engines are better, although they certainly do last longer; but that is largely due to the different points of view of railway management on the different sides of the Atlantic. American managers believe in working the locomotives "for all that is in them," with the idea that if a locomotive lasts ten years that period will have sufficed for important improvements which would relegate it to an inferior position, so that if it is worn out in ten years it may be thrown away and a new one put in its place.

The effect of density of population on engineering design is seen also in marine work. Even slight attention to the shipping in the Atlantic and in the Pacific oceans will emphasise the fact that the very fast steamers are in the Atlantic and ply between New York and the ports of Great Britain, France, and Germany. Indeed, for a long time it was the custom when a vessel was superseded for the Atlantic service to send her around to the Pacific. The reason for this is quite evident to anyone familiar with the cost of high speeds. These are impossible commercially except in very large steamers, and even there they mean a tremendous expenditure in first cost for hull and machinery, while the cost for fuel and wages is also very high. Meeting all these costs is possible only where there is a very large and constant passenger traffic, and obviously this occurs only between New York and the principal ports of Western Europe. In the Pacific the distances to be traversed are about twice as great, and the number of people who can afford to pay the price of high speeds is very limited.

A great many things affect the development of any industry, and it would seem that results sometimes come about rather indirectly. Besides the large, very fast passenger steamers in the Atlantic, there has lately grown up a class of vessels some of which are the largest afloat, but which run at much slower speeds, such as the *Celtic* and *Cedric*, of the White Star Line. Chronologically these ships came after the big express steamers, and it would seem that they are the result of two commercial considerations, one, that the number of very high-speed express steamers which could be supported is limited, and the other, the scientific fact that it is much cheaper to transport cargoes in very large vessels than in small ones. In addition to the fact that it takes a smaller power per ton of displacement to get the same speed in the large vessel, the weight of machinery and of fuel is a smaller percentage of the total displacement, so that a ton of total displacement may not only be transported for less, but this ton of displacement has a larger fraction of useful load carried. A

point in connection with this, of slight historical interest which those who are of an antiquarian turn of mind may look up, is that some twenty odd years ago a tonnage law was enacted in Great Britain which provided that, in reckoning the tonnage for dues, there were certain exemptions on account of spaces occupied by machinery and other things. Some clever constructor, in studying over this matter, found that by modifying the design of the ship the amount of useful carrying capacity could be considerably increased without increasing the measurements on which the dues were fixed. This led to an actual change in the design of a great many vessels purely on this account. Considered as pure engineering, this change was bad. This is not a point worthy of commendation, but it emphasises the important effect which commercial considerations have on what might otherwise be considered a purely engineering matter.

While discussing steamships, attention may also be given to the special type of vessel employed on the Western rivers of the United States, the stern-wheel boat with engines that are considered archaic by engineers whose experience has been on the deep waters of the ocean. This type of boat is mainly engendered by the conditions which it has to meet, but the commercial aspect here also is important. The engines are non-condensing, and seem to defy all the usual laws of economy; but coal in the localities where they run is generally quite cheap, and the dangers to which they are exposed from sand bars, snags, etc., are very great. Indeed, it is usually anticipated that their lives will not be very long, and consequently it is necessary to build them just as cheaply as possible. It is interesting to note, in connection with this, that Stanley, in his book "In Darkest Africa," has a good deal to say about two boats used in his expedition, one a stern-wheeler and the other fitted with propellers. Stanley was not an engineer, but his comments show the difference in adaptability of the two types. The screw boat was nearly always in trouble, while the stern-wheeler gave very little.

There is a monumental illustration of the fact that a machine or structure may be almost perfect from the purely engineering side at the date of its completion, but a failure commercially, in the case of the *Great Eastern.* She was, for more than a generation, the criterion as to great size in steamship construction, although she has been surpassed by a number of the great steamers of to-day. She was a failure commercially because she was built long before the days of economical engines, and when it is considered that to make about sixteen knots her coal bunker capacity was about 10,000 tons, while the modern flyers have nearly half again as much speed and carry only about half as much coal, one of the reasons for the failure may be appreciated. It is probable also that the weight of her machinery to make sixteen knots was as great as that of the modern flyers to make nearly half again as much.

In stationary practice it will often be found true that the most economical plant in steam and coal per horse-power may not necessarily be the cheapest to use. In a certain case, the specifications called for a plant with the avowed intention of getting the utmost economy in the production of power. The plant has been built and is a great success and a beautiful illustration of fine engineering. In this particular case the purchaser did not have to consider the question of interest on first cost; but had the plant been for an ordinary industrial establishment it would really not have been the best engineering, with commercial considerations taken into account. Indeed, a very much cheaper plant would have answered the purpose, and an analysis of the data indicates that a plant which would have used half a pound of coal per horse-power more than this economical one could have been put in for enough less in first cost so that the interest on the saving would have much more than counterbalanced the increased cost of coal.

Commercial considerations are constantly at the front in electrical engineering. This is the day of the trans-

mission of power over great distances by means of electric currents generated by water-power in distant places. The question which confronts the designer from the very start is the cost of copper. He is not permitted to choose a size of wire for his transmission solely from electrical considerations, but he must ever bear in mind the effect of the investment in copper on his interest charges.

Only recently in one of the leading electrical journals a frank discussion appeared of a case where it had been proposed to establish a power plant near some coal mines and transmit the power forty or fifty miles to the place where it was to be used. It happened, however, that the country between the two points was quite level, and there was already a railway, so that it was found, on balancing the costs, that it was cheaper to haul the coal from the mines and have the plant near the place where the power was to be immediately applied.

A discussion has been going on for some years as to the possible displacement of the steam locomotive by electric service, and there is at present by no means an agreement as to just what the outcome will be. Enthusiasts on both sides can figure out results to suit themselves, but the present outlook seems to be at least settled that for branch lines electricity is almost certain to supplant the locomotive. However it may be with the great trunk lines, there has been a remarkable development of interurban electric railways which either traverse regions which the steam roads have neglected, or in many cases parallel the steam roads at a very short distance. The curious thing in the latter case is, that usually, without any falling off in the traffic on steam roads, the electric roads are able to carry a very much greater number of passengers at a decided profit. This seems to be an instance of the commercial aspect of the case being met better by the electric system than by the locomotive. It is obviously uneconomical to haul a single car by a steam locomotive, but it is quite the reverse with running single cars electrically. This enables a very much more frequent schedule to be given by the electric road, and a service which, on the whole, is very much more convenient and satisfactory.

Referring again to the point that "good enough is best," meaning that what will answer fully the requirements of the case is best, even if in itself not the highest product of the art, we may consider the case of certain manufacturing conditions. There are lines of manufacture where the principal use of steam is for heating rather than for developing power in an engine, although engines of considerable power are needed. Now, as is well known, the total heat of exhaust steam is but little less than that of the live steam from the boiler before admission to the engine, so that for heating purposes it is just as useful. This idea has been utilised by taking the exhaust steam from the engines instead of live steam from the boilers for the heating necessary about the works. In many cases the amount of steam necessary to produce the heating effect is considerably greater than would be supplied by the exhaust of a very economical engine, so that in such cases it is decidedly better engineering to use a cheap and wasteful engine, as far as steam economy is concerned, rather than an expensive and economical one. Speaking roughly, the power of the engine is obtained for nothing, so that this really does not enter as a factor at all, and consequently the cheapest engine which will do the work is the best one to use.

There are cases also where steam is used direct from the boilers for heating purposes and where the question comes up whether to use a cheap boiler which will make wet steam or a highly efficient boiler which will make very dry steam. In ordinary work, for use with an engine, the latter is, of course, the one to be chosen; but where all the steam is to be used for heating, the cheap boiler that makes wet steam is the better.

An interesting case where the commercial aspect should be the deciding one is that of steamships for ice breaking only, in harbours where there may be only a few days in the year when they

are used. It must be obvious on a little consideration that steam economy in such cases is absolutely unimportant, and that the first cost of the plant is the thing which should rule. This, of course, means that the cheapest machinery which will do the work and be reliable is that to be chosen.

The machinery for waterworks pumping engines offers a field for consideration of the commercial aspect. If the pumps are located in a district where coal is very cheap it is easy to see that elaborate refinements to secure great steam economy may represent a financial loss, while on the contrary, where coal is high, it pays to get the most economical machinery. In other words, the engineer when scheming his general plan of machinery ought to make up comparative statements which would include not only the cost of fuel, but the interest on first cost and allowance for depreciation, repairs, etc. The machinery which represents the lowest aggregate of these annual costs will be that which is best to use.

We have already considered one particular in which the commercial aspect of the case has a strong bearing in electrical engineering, but it is probably safe to say that in almost every case of the use of electricity this commercial aspect requires careful consideration. This is for the reason, speaking broadly and roughly, that electricity as such cannot be stored. Of course, we have the storage battery, but we cannot store electricity as we do gas or water, for example. The result of this is that the capacity of a station must, in general, be great enough to answer the maximum demand upon it, and thus the nature of the load and the relation of the average to the maximum load have a vital importance in fixing the rates to be charged for current. Where the load is entirely for lighting, the maximum demand lasts for a short time only, so that for the bulk of the twenty-four hours the plant is running at only a fraction of its full capacity. This means that the rates charged must be high.

If the plant is in a district where there is also a great deal of manufacturing, a day load may be obtainable which will materially raise the average load and may permit a lower rate to be charged for lighting. In any case, the rate for power can be made much lower than for lighting, so as to induce consumers to take the current. This matter has been given the most careful consideration by all central station managers, and has led to the design of what is known as a maximum demand meter, which records not only the total amount of current used during the month, but the maximum amount used at any one time. It is obviously only fair that the charge for current should be based partly on the capacity which the consumer requires, as well as on the amount of current he actually uses, and the rates are so adjusted that, for the same total amount of current taken, the price is much lower when the maximum demand is low than when it is high.

The storage battery is used in many cases of a fluctuating load to tide over the peak and thereby enable a smaller investment in engines and generators to accomplish the same result. Storage batteries are, however, expensive, and of relatively short life, so that while offering a solution, it is not a wholly satisfactory one.

An interesting illustration of the effect of commercial considerations was recently brought forward in connection with a scheme for a long-distance power transmission plant in Mexico, where the success of the scheme depends on the combination of an almost constant day load for a long period with a lighting load. It was proposed to install a power plant at a waterfall more than a hundred miles from the City of Mexico, which would supply current for the lighting of the city for about five hours every evening. During the other nineteen hours it was planned to utilise practically the entire power of the plant for the service of one of the railways. There are a number of commercial considerations in this case, one of which is the high cost of coal in Mexico; but it is obvious at once that it would be commercially impossible to transmit current more than a hundred miles for lighting

alone. It is also interesting, in connection with this question of the effect of a constant load in making low prices possible, to notice the result of the installation of the great electric plant at Niagara Falls. When first started, the current was used chiefly in Buffalo and for the railway between Buffalo and Niagara Falls; but gradually an industrial community near the Falls has been developed, for the reason that a number of electrolytic industries which take an absolutely constant amount of current for the whole twenty-four hours, have found it economical to locate their works within a short distance of the power plant. To these concerns the cost of power is the most important element, and as they give an absolutely constant demand, the power company can afford to make very low rates for them.

One of the features of this age of close economies is the manufacture of articles in standard sizes and strictly to gauge so that the parts are interchangeable. This is a case where pure engineering and commercial engineering often conflict. To manufacture cheaply it is absolutely necessary to manufacture in large quantities, and obviously this is possible only when standard sizes alone are made. This means that when the design has been completed and the patterns have been made the rest is repetition work, and the cost of this preliminary work can be distributed over a large number of units.

The tendency of pure engineering is to get out a design for each particular case that arises which will be the very best for that particular case, considered from a purely engineering standpoint, and without regard to cost. It is almost invariably the rule, however, that the special designs or the special sizes required will make the cost of the installation considerably more than if it had been made up of standard units. There is another side also to this question, namely, that standard sizes represent matured experience. When the first units of a new size or design come out, the manufacturer watches them carefully, and if any defects develop or if any points arise where improvement is possible, these will receive attention. After a short time, barring radical developments in the line of work, the design is as good as it can be made. If a consulting engineer either gets out a new design himself, or wants the manufacturer to get out a new design, there will certainly be some features which are, to some extent, experimental, so that the new machine, made exactly to fit the particular circumstances, is hardly deserving of the same confidence as the standard one.

One of the most notable illustrations of the benefit of standard sizes and standard methods of work, because it created such tremendous excitement in Great Britain, was the contract for the Atbara bridge, in Africa, which was obtained by the Pencoyd Iron Works, of Philadelphia, in competition with the world. The bridge was needed in connection with Kitchener's operations against the Mahdi in Africa, and it was highly important that the structure should be completed in the shortest possible time after the tenders were asked. Owing to the system with American bridge builders of putting up standard spans, all parts of which can be quickly manufactured and are sure to go together properly when delivered at their different destinations, the Pencoyd Company was able to guarantee a time of completion very much below anything which was offered by European manufacturers. The bridge was actually completed somewhat within the time they had guaranteed.

European practice for bridges has been to consider each case by itself and arrange for the number of spans, their length, etc., just as if duplication of previous designs were not to be considered. From the standpoint of pure engineering, without regard to commercial considerations, this would probably be the best way; but there is no question that the American method gives a cheaper bridge which fully answers the requirements, and which can be delivered and erected very much more quickly.

One of the special advantages of building standard sizes is that repair parts

can be obtained promptly and cheaply. In some lines of work this is a matter of vital importance, because from the nature of the service the machines do not get very frequent inspection, and when anything has to be replaced it must be done quickly. Where the machines are standard, the manufacturer, as part of his regular work, always has quantities of all the individual parts in stock, so that he can ship them upon receipt of a telegraphic order. Where the machines are special, he cannot, of course, afford to keep spare parts in stock on the chance that an order may come some day; this would represent the locking-up of too much money if the plan were carried out on a large scale. This same objection applies to the purchaser keeping spare parts in stock, for it represents the locking up of his money. Where standard machines are bought, there is every benefit to the purchaser and with a minimum of cost to all parties concerned.

There has been, as we know, ever since machinery existed, a constant tendency to replace hand work by machine work, and while this sometimes means temporarily throwing out of work men who have been following the old line, it undoubtedly assures progress in the long run. Indeed, in many cases it is easy to see that it has saved men from extremely labourious and dangerous occupations, in such work, for example, as charging blast and steel furnaces. While the carrying out of this idea is largely a matter of invention, nevertheless opportunities come to almost every engineer to do something along these lines himself. But here again the commercial aspect sometimes gives the intelligent designer an opportunity to show that the engineer appreciates costs as well as the manager. It may happen, and such cases have actually occurred, that the first idea of doing a piece of heavy work would be on some large machine, but by a slight change in design the same result can be accomplished by hand work; not, indeed, the same work, but the same end. The actual amount expended in wages may be slightly greater, but the use of a large and expensive tool is obviated and this tool is left free for other work.

Too much attention cannot be paid to the great benefit and strength in the work of design which come from an intimate knowledge of shop processes. The best design is not the one which looks neatest on paper, but the one which, while accomplishing its intended result, can be manufactured most cheaply. A knowledge of pattern-making and moulding will thus often enable the designer to provide for reasonable and proper changes in sizes with very little additional expense for pattern-making.

The same is true about machining. Not every shop can afford to have a great bed-plate with portable tools such as have been installed in some large works, and it frequently happens that even heavy work must be set for various operations. If the designer bears in mind that often the cost of setting the piece properly is as great as doing the work of machining on it, he will look out that the surfaces to be planed, the holes to be drilled, etc., are so arranged as to cause as few settings as possible.

When saying that an engineer might almost take as his motto "good enough is best," emphasis must be laid on "enough"; in other words, he must provide adequately for the work to be done. For example, it is worth while to have the materials that come to the works carefully inspected to see that they actually are all that they are claimed to be. Even from the very best establishments materials are sometimes sent out that prove defective, and it is only after the defects have been found that it is realised that they should have been given a more thorough inspection.

It is worth while to take advantage of opportunities to get familiar with processes of manufacture and with what might be called the capabilities of the market in lines not immediately connected with the work one is doing at the time. People do not always stay in one place, and the information thus acquired may be of great value elsewhere. In one case the superintendent of a large

factory saved for his employer at least $50,000 a year through familiarity with other shop practices. Believing, as a consequence of this knowledge, that he might get some of his material more nearly finished than it had been previous to his taking hold of the matter, he took the question up with the manufacturers of the material, who acceded to his proposition almost immediately, with the saving mentioned.

The young engineer should begin at an early day to familiarise himself with the question of costs and become as proficient in this subject as possible. This does not refer merely to costs of material nor even the cost of doing work in the shop, but to all the elements that go to make up the cost of the product as it leaves the factory. We must all realise that the price which is obtained for any article must include not only the cost of the material and of the labour spent on it directly, but of the indirect labour necessary for the production of power and light, as well as the cost of police and repair of buildings, the salaries of engineers, draughtsmen, salesmen and of the officers of the corporation. It is important to acquire familiarity with all these matters, because it may often happen that, when a question of reduction of expenses comes about, unless the matter is thoroughly understood, the pruning knife may be applied in the wrong place.

Articles discussing factory cost in technical papers and magazines have a good deal to say about the relations between direct and indirect labour; but it must be noted in studying this subject that the distinction between the two is, of necessity, very largely arbitrary and based upon convenience and the nature of the business. It would seem at a hasty glance that in a business where the percentage of indirect to direct labour is less than in another it would mean greater efficiency, but this by no means follows. It is sometimes very difficult to charge certain kinds of labour directly to particular orders, and for this reason it is classed as indirect.

For example, the tool manufacture and repair department of a large works will serve a large number of workmen employed in direct labour, and without a considerable amount of accounting it would be difficult to charge the cost to each particular order. The same is true of crane service, the services of the janitors, watchmen, etc. Then, again, it is easy to see that the expenses for draughting and pattern-making are sometimes difficult to properly allot. The immediate work in the draughting-room and pattern shop may be for the first few machines of what are intended to be standards, and if this expense were charged entirely to the first few machines it would make their cost almost prohibitive. Hence, in many cases, this work, which is in the truest sense direct labour, is, nevertheless, classed under the head indirect. Attention is called to this point in order that, when studying this subject, there may be no mistake owing to making a comparison between cases which are not strictly comparable.

A gentleman of great experience in manufacturing recently told the writer that he believed accurate cost keeping was very much less common than was ordinarily supposed, and that he had had opportunities in competitive bidding in which his firm took part, and where they knew from experience the absolute cost of the work, to observe that competitors were taking work materially below cost; in some cases it actually led to the failure of the firms who had made the mistake. There is a great tendency in many places where the work done consists of building rather large machines of varying sizes instead of repetition work on smaller things, to submit proposals necessarily based on estimates. Unless there is a careful system of costs, these estimates in many cases are merely guesses.

Instances are common where estimates are based simply on a price per pound of machinery, predicating these figures on prices for which other contracts had been taken on machinery whose weight was known. This is the very roughest kind of work, and it should never be done if it can be avoided. The reason probably for not

having accurate costs is that it is expensive to establish an accurate cost system; but it is easy to see that when business is carried on without an accurate knowledge of real costs it is quite possible for a single error in estimating to involve a loss greater than the expense of a proper cost system for a great many years.

Along with the matter of costs, and closely allied to it, is the question of factory organisation. With the present tendency towards large works the organisation becomes very complex, so that it is really a huge machine, and just as we study to make all the parts of an actual machine work together harmoniously and for the utmost efficiency, so the same must be done with a great industrial organisation. So important has this become that there are single experts and firms of experts who make a specialty of devising systems of organisation, and while these experts can render valuable assistance in almost any case, the competent manager should be able to outline to them what is needed, leaving to them the elaboration of details. The experts have the advantage of experience gained from many lines of business, while the manager ought to know his own business more thoroughly than any outsider possibly can, however expert he may be.

In the old, easy-going days of works organisation there was too great a tendency to have high priced men doing small work of a clerical nature in addition to the main work for which they were employed, the idea being, apparently, that only a little of their time would be taken. With the modern methods the clerical work coming upon the foreman's office is quite large in amount, and if he had to do it himself it would mean that he would have to neglect, to a great extent, his real work. Most of this clerical work can be done by a boy or a young man at very moderate expense, and it is true economy to relieve the foreman as far as possible of this clerical work so that he can give his time to actual production.

This applies also in the draughting room. At some of the large works there are in the draughting room several hundred employees, and of this number about 20 per cent. are clerks and office boys. It is found very much more economical to have a boy who is paid $35 or $40 a month run after drawings and blue prints and attend to filing them than to have this done by draughtsmen who are getting $150 or $200 a month.

Every engineer is now familiar with the fact that in all modern works of any size the making and repairing of tools is managed by a special department of the works. The "good old days," when a gang of men would stand in line waiting for their turn at the grindstone, have gone by. In a modern shop, when a tool needs grinding, it is sent to the tool department and another one, all ready for use, is obtained at once. It is easy to see how much more economical such a method is, for the preparation of tools is kept in the hands of people who are doing nothing else and who are necessarily much more expert than the general workman would be, while the latter does not waste time in waiting for a turn at the grindstone. Indeed, where the premium system of payment prevails, a workman would not be willing to wait for a turn to sharpen a tool, because that would mean lost time to him. The great benefit of the premium system is that it prevents lost time by making the men see the advantage to them of so arranging matters as to have no "loose ends." The increased production does not mean harder physical work on their part, but more intelligence applied to the work.

MULTI-CYLINDER LOCOMOTIVES

A REVIEW OF THE WORLD'S PRACTICE IN MULTI-CYLINDER SIMPLE AND COMPOUND LOCOMOTIVES

By J. F. Gairns

PART II.—THREE-CYLINDER COMPOUND LOCOMOTIVES

THE compounding of locomotives has been a favourite subject of study among locomotive engineers for the last half-century, though it is only during the latter part of that period that anything of importance has been done. As would be expected, the first engines had only two cylinders, one high and one low-pressure, and the names of Mallet, Worsdell, von Borries, Gölsdorf, Lindner and others are well known in connection with the subject. But before the two-cylinder compound locomotive had emerged from the experimental stage various three-cylinder systems had been proposed, and even to-day, when four-cylinder systems are being adopted everywhere, builders of three-cylinder compound locomotives are not wanting, and the engines still in use are given first-class work to do.

What may be termed the simplest arrangement of the three cylinders in a compound engine is that proposed in 1879 by Mallet and in 1889 by Lapage. This is a direct development of the two-cylinder system to avoid the inconvenience of a very large low-pressure cylinder in powerful engines, and consists in using in place of one large cylinder two comparatively small low-pressure cylinders on one side of the engine, one cylinder being superposed upon the other, and the two piston rods being connected to one large cross-head, after the fashion employed in the Vauclain four-cylinder compound locomotives.

Fig. 23 shows the arrangement on the low-pressure side of the engine. So far as the writer is aware, no locomotive on this system has been built; but it is only very recently that the dimensions of the low-pressure cylinders, even for the biggest engines in use, have become inconveniently large,—that is, for the locality in which engines work,—and we may yet see the double, superposed, low-pressure cylinder system in use, though a four-cylinder system will probably be preferable in most cases.

The more general practice has been, however, when using two low-pressure cylinders to one high-pressure cylinder to provide each cylinder with its own connections and thus obtain the advantages of balancing and a more regular turning effect, even at the price of a third set of mechanism.

The first tangible suggestion of an engine with one high-pressure cylinder and two low-pressure cylinders is due to Jules Morandiére, the locomotive engineer of the Northern Railway of France,

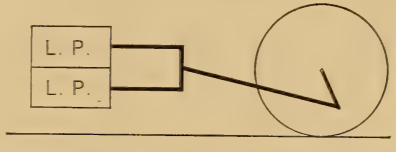


FIG. 23.—TWO LOW-PRESSURE CYLINDERS ON ONE SIDE

who, in 1866, brought out a design for such a locomotive. Fig. 24 shows the general arrangement in this engine. There were to be eight wheels, all driving, coupled in two pairs,—not in bogie frames, however,—and the forward set were to be driven by two outside low-pressure cylinders receiving steam from one inside high-pressure cylinder driving

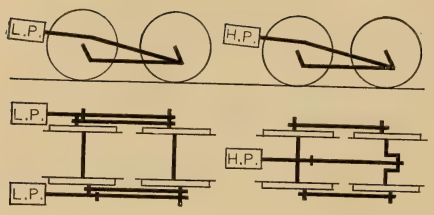


FIG. 24.—MORANDIÈRE'S THREE CYLINDER DESIGN OF 1866

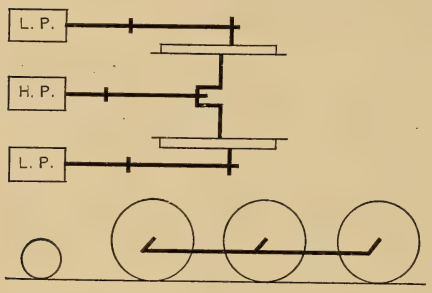


FIG. 25.—A FRENCH MOGUL TYPE

the rear set of wheels. The three cylinders being approximately all of one size, there would be no difficulty about using live steam in all of them at starting and at other times when necessary, and exhausting directly to the air. This design was never carried out, and it still remained for M. Mallet to achieve distinction ten years later as the first engineer to produce a practical compound locomotive.

He did not concern himself to any extent with three-cylinder compound locomotives except the design just mentioned, and the writer is not aware that he seriously considered even that one; but there are few four-cylinder designs which are not anticipated to some extent by his suggestion. On the Bayonne & Biarritz Railway, where his first triumphs were achieved, it was proposed by a M. Andrade, about the same time that M. Mallet brought out his first engines, to build some three-cylinder engines with one high-pressure cylinder and two low-pressure cylinders, and it is probable that M. Mallet had something to do with these.

Speaking before the British Institution of Mechanical Engineers in 1877, the subject of discussion being Mallet's compound, two-cylinder locomotives, Mr. F. W. Webb, who, in practice later on, adopted a different arrangement, said that he had under consideration a three-cylinder arrangement with one high-pressure and two low-pressure cylinders. The first engine built with this arrangement of cylinders appears to have been a Russian engine constructed by Messrs. Struwe, of Kolomná, in 1881; no further particulars of it are available.

In 1887 M. E. Sauvage, then locomotive engineer of the Northern Railway of France,—it is curious to note the important part the engineers of this line have taken in connection with multi-cylinder locomotives of all kinds,—designed and built a six-coupled locomotive of the Mogul type, with one inside high-pressure cylinder and two outside low-pressure cylinders, all driving on one axle. This engine is shown diagrammatically in Fig 25. It has never been duplicated, but is, however, still at work. In some quarters this engine has been attributed to M. de Glehn, but this statement is contradicted by him.

Since that time many engines on this system have been built on the European Continent for various railways. The principal builders of these engines are the Swiss Locomotive Works, at Winterthur, who, until recently, have made them a speciality. Probably there is no country in the world which contains so

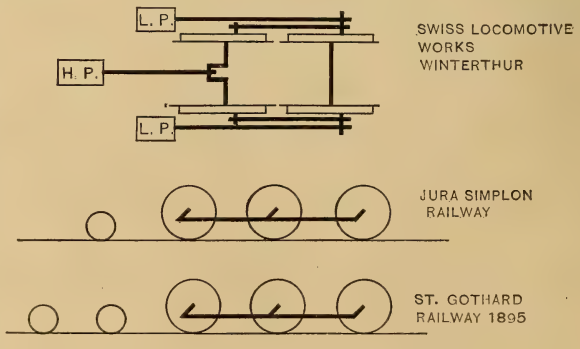


FIG. 26.—A SWISS DESIGN

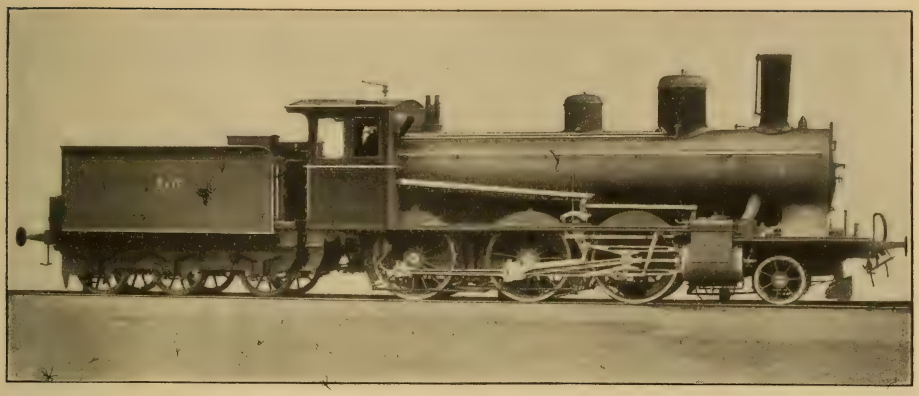


FIG. 27.—A THREE-CYLINDER COMPOUND "MOGUL" LOCOMOTIVE ON THE JURA-SIMPLON RAILWAY, BUILT BY THE SWISS LOCOMOTIVE & MACHINE WORKS, WINTERTHUR, SWITZERLAND

many three-cylinder compound engines as does Switzerland, and the firm mentioned are still building them, though on some of the railways four-cylinder engines are now coming into use. It has been stated that nearly all Swiss locomotives are compounds. Be that as it may, the three-cylinder compounds outnumber those of any other description.

In the engines built at the Winterthur Works the inside high-pressure cylinder drives the front coupled axle and the low-pressure cylinders drive the second coupled axle, as shown in Fig. 26. Most of these engines have six-coupled wheels, with a leading radial axle (Mogul type), or a leading bogie (ten-wheel type).

Fig. 27 shows a Mogul locomotive for the Jura-Simplon Railway. The first engine of this type was delivered to the line in 1896, and was the thousandth engine turned out from the Winterthur Works. Since then a considerable number of similar engines have been supplied. In 1895 a six-coupled bogie engine was built for the St. Gothard Railway. At the same time a four-cylinder engine of otherwise similar construction was also supplied, so that the two systems could be compared. The four-cylinder system was, however, preferred for further engines on the St. Gothard line; but most other Swiss railways largely employ three-cylinder engines.

The Swiss works have also built a few three-cylinder locomotives for railways of other European countries, and the John Cockerill Company, of Seraing, Belgium, have supplied some to the Württemberg State Railways. Besides these, however, the type is not generally in service.

In 1897 Mr. Sandiford experimented on one of the Indian railways with a three-cylinder engine with one high-pressure and two low-pressure cylinders driving cranks at 120°, the arrangement being similar to that shown in Fig. 25. When working all cylinders simple, the results were admirable on the heavy grades which are to be found on some of the Indian lines; but as a compound the results were not at all satisfactory, and the engine was soon reconverted to an ordinary two-cylinder simple engine, being then quite powerful enough for its work.

In Great Britain there are three locomotives with three cylinders, two low-pressure and one high-pressure. The system employed is that due to Mr. Walter Smith, of the North-Eastern Railway. One of the engines is on the designer's own line; the two others have lately been built by Mr. S. W. Johnson, at Derby, according to Mr. Smith's system, for the Midland Railway. In these engines all cylinders drive the same axle, and all three locomotives are of the four-coupled, bogie type. Good results are reported with these engines

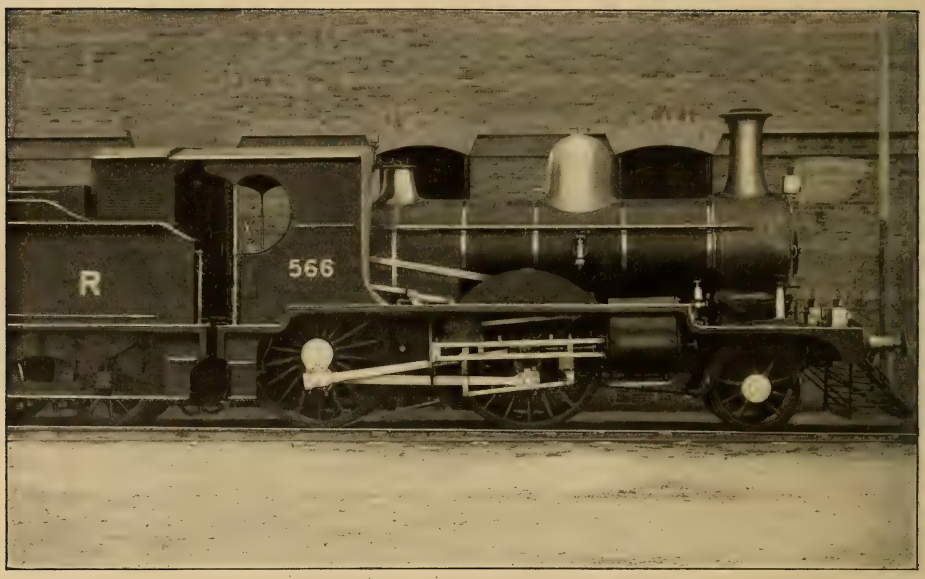


FIG. 28.—A WEBB THREE-CYLINDER, COMPOUND ENGINE ON THE OUDE & ROHILKUND RAILWAY, INDIA. THIS ENGINE WAS FITTED WITH COUPLING RODS

under trial. So far, however, the North-Eastern engine is without a companion, notwithstanding that, as a compound, it is about six years old; the Midland engines, as stated, are of recent date, and have given rise to some exaggerated newspaper reports concerning their marvellous doings.

The cylinders of North-Eastern engine are,—high-pressure, 19 by 26 inches; low-pressure, 20 by 24 inches. The driving wheels are 7 feet in diameter, and the steam pressure is 175 pounds per square inch. The Midland engines have high pressure cylinders 19 by 26 inches, and low-pressure cylinders 21 by 26 inches. The driving wheels are here also 7 feet in diameter, and the steam pressure is 195 pounds per square inch.

Great Britain has but two engineers to uphold the principle of compounding in locomotives; but their work has been on a sufficiently large scale to make their engines known all over the world, although other engineers have contributed, in a small way, to the compound principles. Mr. T. W. Worsdell, for example, is well known, in conjunction with Mr. A. von Borries, of Berlin, for his two-cylinder system which was in use on the Great Eastern Railway, where all engines were long ago converted to simple expansion; on the North-Eastern Railway, where many engines were converted to simple expansion, but a large number, principally goods engines, still remain compound; on the Belfast & Northern Counties Railway, of Ireland; and, to a very large extent, on Continental, principally German, railways.

The other of the two men, Mr. F. W. Webb, former chief mechanical engineer of the London & North-Western Railway, has not only done very valuable work as a designer of three-cylinder compound locomotives, and, later, of four-cylinder engines, but was also one of the pioneers in the work of producing a practical compound system applicable to locomotives.

M. Anatole Mallet was, as is universally admitted, the first to successfully grapple with the problem, but Mr. Webb takes second place. Mallet commenced with his two-cylinder system in 1876, and it was not until 1878 that Mr. Webb experimented upon it. In 1881 Mallet patented his well-known system,

the first engine built under it,—the *Experiment*,—coming out in 1882. In 1883 and 1884 twenty-nine others were built (Fig. 29).

It is not necessary to describe the work of Mr. Webb in detail, for it has been the subject of many writers on locomotives. Suffice it to say that in the years 1884 to 1888 the "Dreadnaughts," a more powerful class than the "Experiments," came out, forty in number; in 1889 and 1890 the ten "Teutonics" were built; in 1891, 1893 and 1894 the ten long-boilered "Greater Britains" appeared; and in 1894 and 1898 the ten long-boilered "John Hicks" were added. The system has been applied to four tank engines, as experiments only, and, with an important difference, to a very large number of three-cylinder, eight-coupled goods engines.

Briefly stated, Mr. Webb's system, as expressed in his patent specification, comprises "locomotives with two pairs of driving and carrying wheels, driven separately, one pair being driven from two cylinders and the other from one or two cylinders, one set of cylinders working steam direct from the boiler and exhausting to the other cylinder or cylinders, the axles of the two pairs of driving wheels being uncoupled."

In practice, the system consists in the use of two outside high-pressure cylinders, set back on the frames and driving the rear pair of driving wheels; and one large low-pressure cylinder, receiving steam from both high-pressure cylinders, driving the front pair of driving wheels, the wheels being uncoupled. The substitution of two smaller low-pressure cylinders for the one large one, as covered in the patent specification, would be a natural development, but was never carried out with uncoupled wheels and separate axles. It has, however, since been adopted by Mr. Webb with his four-cylinder system, in which all the cylinders drive one axle.

The fact may be worth mentioning that one tank engine was built according to a special and peculiar arrangement, covered by Mr. Webb's patent already mentioned. This had a third axle coupled to the second,—the high-pressure,—driving axle, so that the engine had a single pair of driving wheels, and also four coupled ones, six drivers in all.

As applied to tank engines the system was not sufficiently successful to warrant the engines being multiplied; indeed,

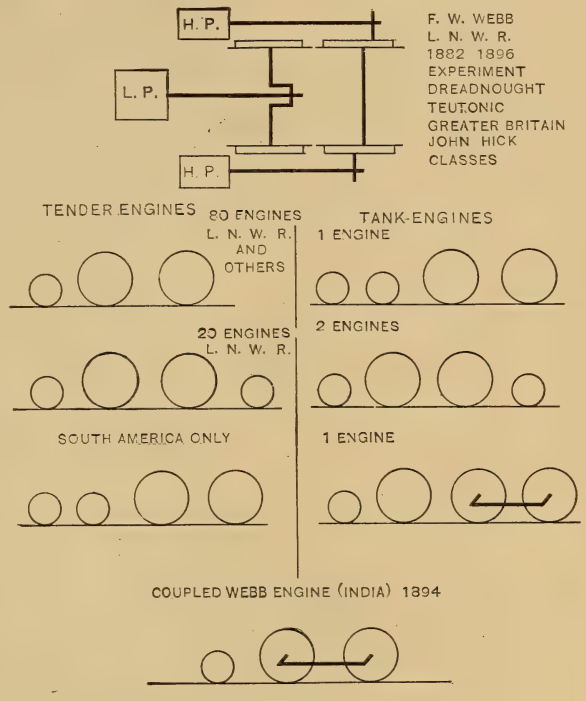


FIG. 29.—THE WEBB COMPOUND LOCOMOTIVE

Mr. Webb admits that they were never more than experiments. But with express engines on this system, despite the very adverse criticisms of engineers, especially in the early years, wonderful results have been achieved, and to-day all the engines are doing splendid work due allowance being made for their age and power.

The Western Railway of France still

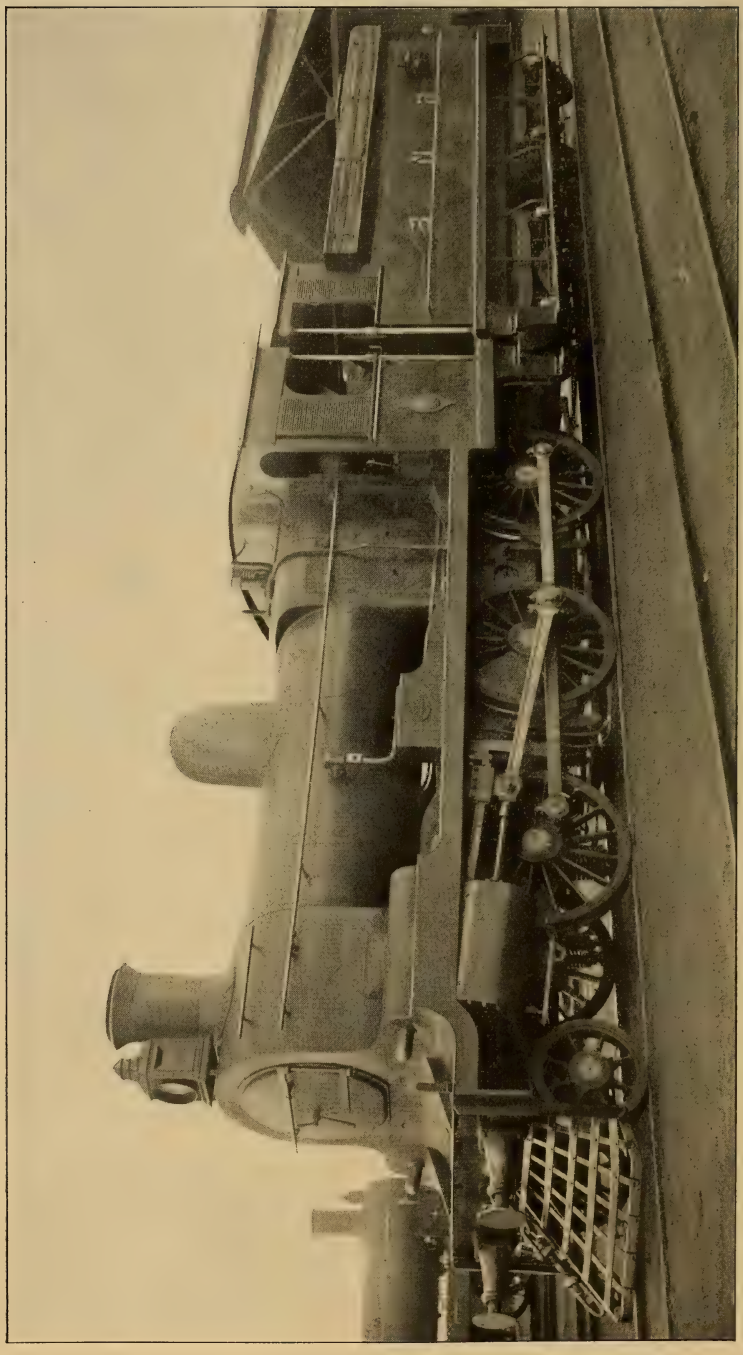


FIG. 30.—A THREE-CYLINDER COMPOUND GOODS LOCOMOTIVE ON THE BENGAL & NAGPUR RAILWAY, INDIA. DESIGNED BY J. RIEKIE

has one or two engines of this type, supplied in 1884. The Pennsylvania Railroad in 1886 purchased one, and this engine was subjected to very severe trials in the mountain districts, with good results, as reported at the time. Several of the engines went to Brazil, and others are to be found in India. Some of the South American engines were constructed with bogies in front.

The non-use of coupling rods has always been a very fruitful source of controversy, and many capable engineers have expressed an opinion that with coupling rods the few disadvantages of Mr. Webb's three-cylinder engines would be removed; but Mr. Webb has never agreed to the use of coupling rods, even on one of the engines by way of experiment. In India, however, Mr. John Riekie in 1894 induced the director of the Indian State Railways to have coupling rods fitted to one of the Webb engines, the three connecting-rods being arranged to drive at angles of 120 degrees. A very steady-running engine resulted which did good work for some time. It is shown in Fig. 28.

For goods service Mr. Webb uses only one pair of driving wheels, all cylinders being abreast and driving on to one axle which is coupled with three other axles to form an eight-coupled engine (Fig. 31). More than a hundred of these engines are in use, and there is no doubt whatever about their capacity for excellent work.

Mr. John Riekie, at present locomotive superintendent of the Eastern Bengal State Railway of India, is the only other locomotive engineer who uses two high-pressure cylinders to one low-pressure cylinder, and he stands quite alone in his views on the subject of cylinder ratios and the relative work to be done in the high and low-pressure cylinders.

In a simple engine it is usual to cut off early, but in most compound engines a late cut-off has to be used in the high-pressure cylinders; hence one reason for the general use of small high-pressure cylinders. Mr. Riekie, however, aims at retaining this early cut-off with the compound engine, and uses normal-sized high-pressure cylinders. The three cylinders are arranged to drive on to one axle at angles of 120°, and, in exhausting, one high-pressure cylinder is in communication with the low-pressure cylinder for about one third of the stroke and then the other high-pressure cylinder commences to supply steam. In practice, Mr. Riekie is able to cut-off in the high-pressure cylinders at from 20 to 25 per cent., as in a simple engine, and, therefore, to thoroughly utilise all the work represented by the steam.

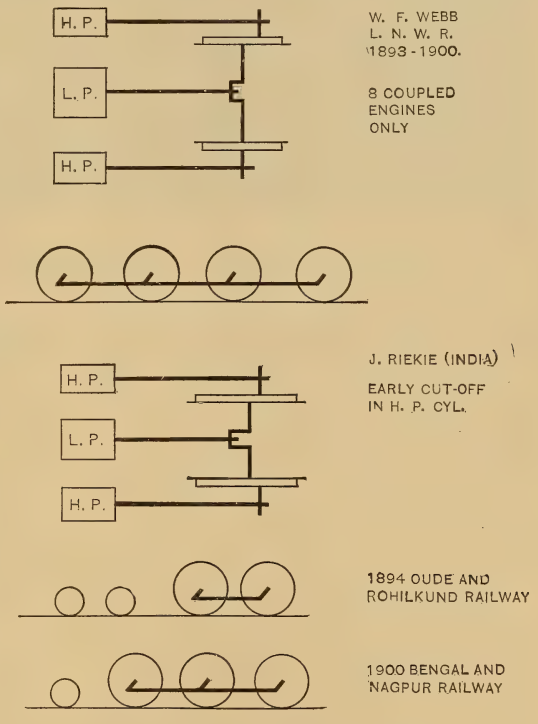


FIG. 31.—WEBB AND RIEKIE TYPES

He uses cylinder ratios altogether different from those of other engineers,—about half that of most compound engines,—believing that before steam is re-used in the low-pressure cylinder it must be first thoroughly used in the high-pressure cylinders to obtain the best results. He, therefore, adopts a

FIG. 32.—A THREE-CYLINDER COMPOUND LOCOMOTIVE,—RIEKIE SYSTEM,—ON THE OUDE & ROHILKUND RAILWAY, INDIA

low-pressure area in the ratio of 2½ to 2 for the combined high-pressure cylinder areas, which, with the early high-pressure cut-off, allows him to work down from, say 180 pounds per square inch to less than 20 pounds per square inch. Indeed, he claims that with light loads the terminal pressure may be worked down to as low as 5 pounds per square inch.

The first engine fitted (in 1894) according to this system was one of the Webb compounds belonging to the Oude & Rohilkund Railway, shown in Fig. 32. It was intended that the cylinder diameters should be 18 and 28 inches, in place of the original 12 and 24 inches. Eventually, however, 14 and 24-inch cylinders were used. This engine proved a serviceable machine in practice, and compared favourably with other engines, though its dimensions were not altogether what Mr. Riekie desired.

When he was appointed locomotive superintendent of the Indian East Coast Railway (Madras Presidency), on which there were a number of two-cylinder compounds with cylinders 20 and 28 inches by 26 inches, which were not satisfactory in some respects, he converted one of these engines by adding two high-pressure cylinders outside to suit the large low-pressure cylinder, the other inside cylinder being disconnected and not used, its crank being allowed to run idle. The engine was then able to take the heaviest loads up the grades when working with a 25 per cent. high-pressure cut-off, and also steamed freely at the full pressure of 180 pounds, and the early cut-off, though it had previously been impossible to maintain a full head of steam when working hard in its original condition with one high-pressure cylinder and a late cut-off. This engine, shown in Fig. 30, now has 20 and 31½-inch cylinders, the inside cylinder driving a single crank axle, and is now at work on the Bengal & Nagpur Railway. The inside crank webs were extended to form balance weights.

A lack of suitable valve gear has been a hindrance to the development of this system, as by ordinary gears it is well-nigh impossible to combine an early cut-off and a late exhaust; but Mr. Riekie has patented an improvement in valve gears which he hopes soon to put into practice by which he can obtain an

85 per cent. release with a 20 per cent. cut-off, and which also permits the lead to be varied to give full, or nearly full, port-opening, as may be required, without varying the cut-off.

At present the system is in its experimental stage, the two engines built being conversions, and not specially constructed engines; but good results appear to be assured, and it is likely that soon, with the improved valve gear fitted, the Riekie system will take its place among those which are already in regular use.

In view of the fact that in Great Britain cylinder dimensions are, and must be, limited, such diameters as 24 and 38 inches for a two-cylinder compound,—equal to two high-pressure, 24-inch cylinders,—being impossible, and as for four-cylinder compounds it is necessary to use small high-pressure cylinders because of the impossible diameters required for low-pressure cylinders to correspond with large high-pressure cylinders, it may be that Mr. Riekie's system will meet the case, for, with two 24-inch high-pressure cylinders (about the possible maximum), he would require only one inside 38-inch cylinder. With such an engine it would be possible, under ordinary conditions, to cut off at from 10 to 15 per cent. of the stroke, thus using no more steam than with 15-inch cylinders, but expanding to a greater degree.

It would be an interesting experiment if Mr. Webb, or his successor, could arrange to substitute two 19-inch cylinders for the present 14-inch high-pressure cylinders, and, of course, alter the valve gear accordingly.

One of the first of Mr. Webb's three-cylinder, eight-coupled goods engines was at one time tried with the cranks at 120 degrees and partially adapted according to the Riekie system; but as the cylinder ratio was not altered, it was not to be wondered at that the engine thus fitted was a failure, and was soon altered back to Mr. Webb's own arrangement, the high-pressure cranks being placed at 90° and the low-pressure crank at the usual angle.

Part III., to appear in the February issue, will be devoted to four-cylinder compound locomotives.

THE HIGH-MINIMUM WAGE

THE EVILS OF ARTIFICIAL CLASSIFICATIONS OF LABOUR

By Marcus M. Marks

The evils of artificial classifications of labour, whether by the minimum or the maximum wage, or by certain intermediate grades, are well set forth by Mr. Marks in the following paper, which was specially prepared for discussion recently at one of the sessions of the National Civic Federation. Its publication here has been made possible by the courtesy of Mr. Marks and of the secretary of the Federation.—THE EDITOR.

WITH the hope of obtaining a larger share in the profits of business, and of limiting the power of the employer to reduce wages; the union workmen in many trades have endeavoured, with more or less success, to establish a minimum wage below which no member is allowed to work, except by special indulgence. The intent of the regulation, it is stated, is to help the weak without injuring the strong; to assure the slow workman of at least a fair living wage, and to raise the general standard of labour. These purposes are certainly commendable. The word minimum, from its very derivation, conveys the idea of smallness, and the minimum wage, as it exists in

theory, meets with little opposition. In practice, however, it usually happens that with the best motives the unions push the minimum up so high that it becomes the maximum as well. Let us consider the consequences of such action.

1.—Does the minimum wage, set at a high standard, or, in other words, the "high-minimum" wage, really help the inferior workman?

2.—Does it help the superior workman?

3.—At what cost does it attempt to raise the standard of labour?

If all the workmen in any trade remained in steady employment after the establishment of the high-minimum wage, the inference might justly be drawn that the inferior workman was protected and benefited by such wage regulation. But it invariably happens in practice that, when this rule is imposed, employers soon begin to weed out those workmen who do not produce enough to be entitled to the wages stipulated. What becomes of the unfortunate ones thus thrown out of employment? They cannot always adapt themselves to new and strange conditions in other trades where the minimum wage rule may not be operative; and even if they could so adapt themselves, they would not readily find suitable positions. The usual result is idleness, discouragement, poverty, and loss of self-respect.

From an economic standpoint it is to the employer's advantage to give space in his shop to the quickest and best workmen. His unit of expense is reduced when he increases his per-capita output. If he allows slow and old men in whom he has become interested to occupy positions that pay them the same proportion of wages for their labour as is received by the superior workman, and suffers the loss which comes from their reduced output, where, then, is the injustice or injury to labour? Why should a majority of the workmen, by a rule of their own contrivance which aims to force the payment of partly unearned wages to these under-average men, cause such embarrassment as the discharge of the latter would bring about? Is this benefiting the weak?

"Yes," says the hearty supporter of the high-minimum scale; "we admit this hardship, but we must look to the greatest good for the greatest number. In the march of progress the weak must drop out."

That sounds very well, but in the matter of wages cannot the greatest good to the greatest number be brought about without the sacrifice of those who need protection most? Artificial barriers in the way of the easy workings of economic laws are very apt to bring injury in the long run. Were the cases of inability to earn the so-called minimum wage rare, the expedient which is often proposed, namely, to make exception in favour of the slow and the old, might answer; but the earning capacity of men has a wide range, and the high-minimum wage crowds out not a few individuals, but usually a minority class of workmen. If the demand for help happens to be very great, and there is work for all, the employer is often forced to pay the slow workmen more than they earn, and, to counterbalance this increased outlay, he is apt to average up at the expense of the better workmen by limiting the pay of the latter to the stipulated minimum.

As has been stated, the minimum wage is usually pushed so high as to become a maximum as well, so that in effect all workmen of any one class receive substantially a uniform wage. In view of the fact that Nature has not endowed all alike, and that practice and experience do not develop equal proficiency in all, it soon appears that the sense of justice of the quick, skilled workman is outraged by this wage-levelling rule.

Why should he deliver, for the same wage, a larger product than does his slower neighbour? The result is that the superior man retards his speed, thereby injuring himself, and at the same time doing an injustice to his employer. By adopting the "go-easy" idea to which has been attributed the waning prestige of British manufactures, the bright, quick, able workman be-

comes a machine and soon sinks into mediocrity. By disuse, his extra power soon disappears, his individuality is lost, his chance of raising himself from the ranks is gone, his hope for the future destroyed. The uniform wage creates a dead-level which is against the laws of Nature, and which tends to make a permanent class of workmen and another of employers, instead of allowing a constantly shifting personnel such as is naturally fostered by a system that encourages individual development.

It is reported that in some trades in which the uniform wage was introduced, a number of superior workmen voluntarily reduced their wages in order not to embarrass their union in carrying out the rule. This self-sacrificing act calls for admiration; its intention is excellent, but the result of the "dead-level" is just as pitiable.

Recognising the decided inequality in the ability of workmen, some unions now discard the theory of the single minimum wage, and arrange grades of pay for classes of men of varying proficiency. For example, $3 may be set as the daily wage of the slower and inferior workmen, $4 for the average mechanics, and $5 for the best class. This is undoubtedly a step in the right direction. However, it still leaves uncared for those who do not come up to the earning capacity of $3 a day, as well as the very able men who can earn more than the $5 limit. It also throws into the same class numbers of men who are unequally endowed, some of whom, for instance, graded as $4, might easily earn $4.25 or $4.50 per day if additional scales for such amounts were allowed.

Why, then, these artificial classifications? Why should not every man receive pay for exactly what he produces? Who has the moral right to say that the maximum capacity of a man of superior strength and ability should be limited to $5 a day, whether or not such a man can earn more without in any way injuring his health?

The maximum wage is as artificial and dangerous as the minimum. It is often insisted on by the unions because of the fear that the quick workers, sometimes called "pace-makers," will be used by the employer as a means of cutting the wages of those who fall below the high standard thus set. In periods of commercial depression, when there are two workmen ready to compete for each piece of work, this method of wage-cutting has been effectively used by some unfair employers. But in prosperous or even normal times, when most workmen find a market for their labour, the attempt to cut wages in this way will be unsuccessful, because the men will refuse to work for an employer who thus tries to crowd the pay below prevailing rates. The trade-agreement can be made an effective safeguard against rate-cutting where pay by piece-work prevails, and a protection against "sweating" where payment is made by weekly wage.

It is claimed by some unions that favour restriction of output that the pace must be kept down and the quick man's earnings limited, because under so called "rush" conditions quantity is turned out at the expense of quality. This contention seems hardly ingenuous. It is perfectly safe to trust the employer to guard against the deterioration of the quality of the work, as it is very much to his interest to maintain the reputation of his product.

Now let us turn our attention to the claim that the establishment of the minimum wage (and this may be interpreted practically as a high-minimum wage) raises the standard of labour. The ancient Romans are said to have believed that by dipping their infants into the cold waters of the river Tiber the babes absorbed some marvelous power that produced the vigorous youths of whose physical prowess Rome was so justly proud. The fact is that the shock of the cold water killed the tender and weakly infants, and only those naturally strong and rugged survived to "raise the standard" of the physical manhood of the Romans. In similar manner the establishment of the minimum wage, by throwing out of employment the weak and the slow, may raise the standard of labour. But at what a cost!

Although every fair man must hail

with delight any legitimate method of raising the standard of labour, the high-minimum wage and the uniform wage to which it usually leads must eventually be abandoned in favour of a wage plan that is more natural, and, in the long run, more effective. A moderate minimum could be maintained provided exceptions be freely made in favour of the slow and the old. These exceptions should not be arbitrarily made or arbitrarily refused by the unions, for such action would unnecessarily antagonise the employers, create ill-will, and tend to impair the future usefulness of the unions.

The writer's proposition is:—

1.—Yearly agreements should, whenever possible, be made between employers and wage-earners, regulating wages, hours, and general conditions of employment.

2.—Among other conditions, it should be stipulated that there be no reduction in piece-wage, or its equivalent in time-wage, during the term of the agreement. This will assure workmen that the larger output of the ablest and quickest will not militate against the interest of the others.

3.—If a minimum wage be agreed to, the exceptions thereto shall be determined by joint conference of employer and employee.

This last point cannot be made a matter of arbitration because, in the final issue, the employer must reserve the right to discharge, and the employee the right to seek other employment; but a conference either between individual employers and wage-earners, or between representatives of employers' associations and trade unions, would in most cases lead to a fair adjustment of wages.

A proper apprentice system would minimise the number of unfit men, by directing the youth in his early experience from a trade for which he showed no fitness to one in which he might more readily acquire proficiency. A rigid enforcement of child labour laws by the government would also take a burden from trade, and remove a possible reason for the need of a minimum wage.

The general plan of agreement here outlined is calculated to bring the greatest good to all the employees, skilled and unskilled, strong and weak. The standard of labour will unquestionably be raised as a result of these conferences and agreements. Employers will go to the full limit of their ability in arranging conditions of labour much more willingly in such friendly meetings than when seemingly arbitrary demands are made upon them; and, on the other hand, the wage-earner will often moderate his claims and avoid serious errors by acquiring at these conferences information which he would not otherwise obtain regarding the trade situation. Misunderstandings,—the cause of the majority of labour troubles,—are usually cleared up at the "round table," and it is there that the present practical abuses of the so-called "minimum" wage could be removed without friction, and without detriment to the cause of labour.

HYDRAULIC POWER IN FOUNDRY AND MACHINE SHOP

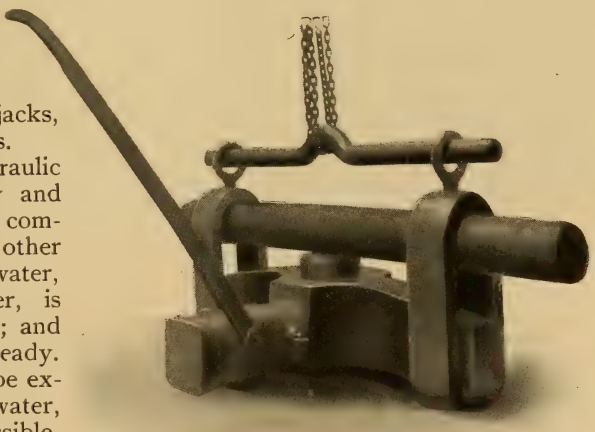
By Joseph Horner

HYDRAULIC power does not figure so prominently in either foundry or machine shop as it does in boiler shops, in steel mills, and in many heavy stamping shops. The great wealth of hydraulic machines lies in the boiler and plating shops, where they have little rivalry. Elsewhere they are being hard pressed in consequence of the rapid advances of electricity and of compressed air. There is, nevertheless, a good field yet for the old and trusted agent,—pressure water,—in these two departments, from which there is at present no indication that they will be displaced.

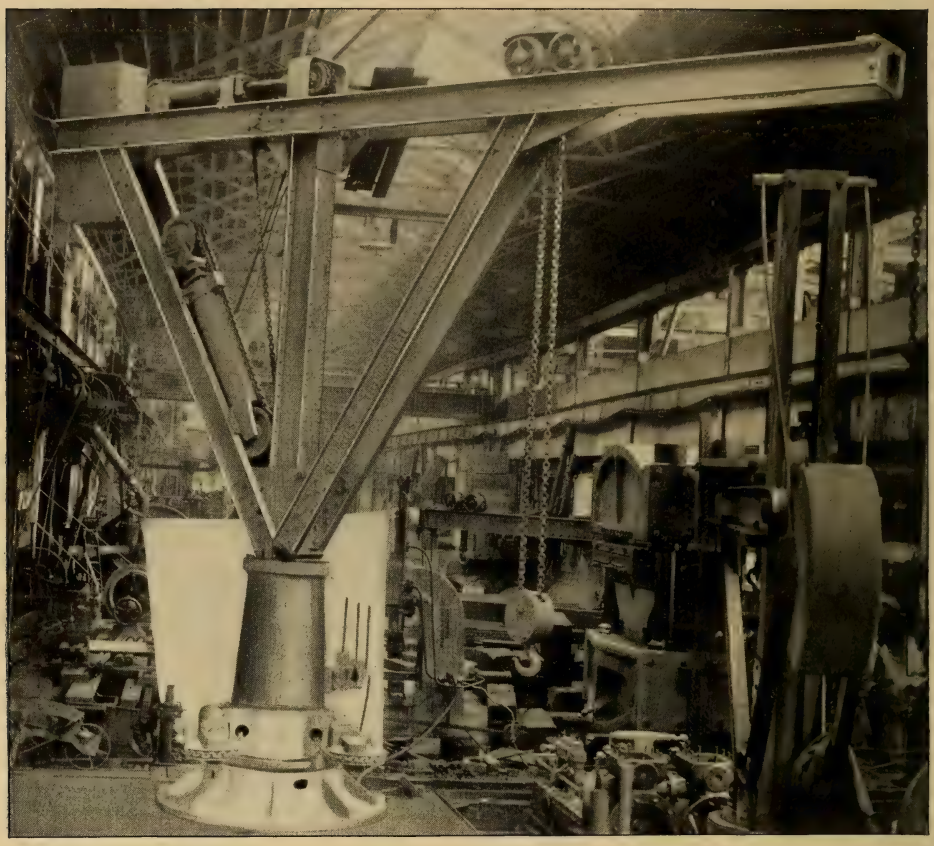
The work of hydraulic power in the machine shop and foundry lies in operations that must be performed slowly, steadily, with great precision, and backed up with considerable force. These operations include hoisting by fixed cranes, the work of cupola hoists, the moulding of heavy work by machines, the various duties of wheel presses, arbour presses, shaft straighteners, test pumps, jacks, and allied forms of apparatus.

The advantages of an hydraulic installation for the foundry and machine shop are that its cost compares favourably with that of other power installations; that no water, and consequently no power, is wasted when not in service; and that the action is perfectly steady. When great energy has to be exerted through a small space, water, being practically incompressible, gives better results than any other agent. The mechanism, though massive, is simpler than that of the systems that are in competition with it. The water pressure employed in shops usually ranges from about 750 to 1500 pounds per square inch, and much higher for test pressure pumps.

There is now a much larger range for selection in pumps and engines for hydraulic service than formerly. Knowing the number of gallons per minute required for service, either non-geared or geared pumps are selected, with rams of suitable size and length of stroke. Pumps are either high or low-pressure pumps. In the best designs the barrels are either of gun metal or of steel. When steel is used, the valve seats are of hard gun metal. Valves and glands also are of that metal. In the geared pumps the gears are of double helical form, or are plain spurs cut in cast iron. Some recent pumps are electric motor-driven, their first pinion,—that on the motor spindle,—being of rawhide. For



HYDRAULIC SHAFT STRAIGHTENER FOR LATHE WORK. MADE BY MESSRS. YOUNGS, RYLAND STREET WORKS, BIRMINGHAM, ENGLAND



AN HYDRAULIC 5-TON INDEPENDENT ALL-AROUND SWING CRANE. MADE BY MESSRS. FIELDING & PLATT, LTD., GLOUCESTER, ENGLAND

large installations duplex pumping engines are preferable,—either simple or compound, engines and pumps self-contained on the same base-plate. Some engines are designed for use without an accumulator. In this case they are of the three-cylinder type, discs take the place of the usual fly-wheels, and a relief valve is provided to prevent excess of pressure.

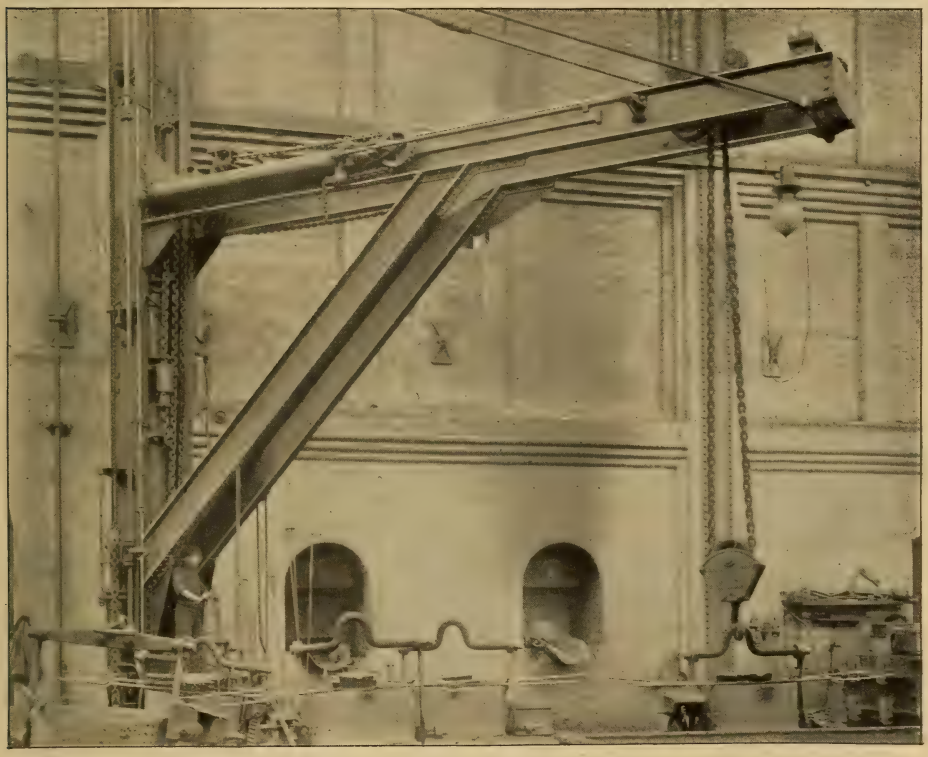
The accumulator,—the intermediary device by which the pressure-water from the pump is made to lift a load, which, on its descent by gravity, supplies the pressure-water to the various machines,—is the artificial equivalent of a natural head of water, producing a constant pressure, controllable by a valve.

There are two main types of accumulators, the ordinary or direct, and the inverted. The difference between the two is that in the direct type the ram moves up and down in its cylinder, while in the other the cylinder works upon the ram. Besides this main distinction there is another between the weight-case type and the ring-weight type. In the first a cylinder casing of riveted plates is loaded with heavy materials, such as slag; in the second a series of cast rings in segments is carried on a bottom ring, which, in turn, is supported by stout bolts dependent from a cross-head on the ram. In large accumulators the cross-head is usually controlled in its vertical movements by channel irons in timber supports, but in the smaller sizes these are frequently dispensed with, the accumulator being then independent of extraneous control. In those of larger

size also, up to about 8 inches diameter by 12 feet stroke, guide rails are sometimes dispensed with by casting guides on the cylinder for pulleys, which are recessed in the bottom weight, to run up, without the weight being turned round.

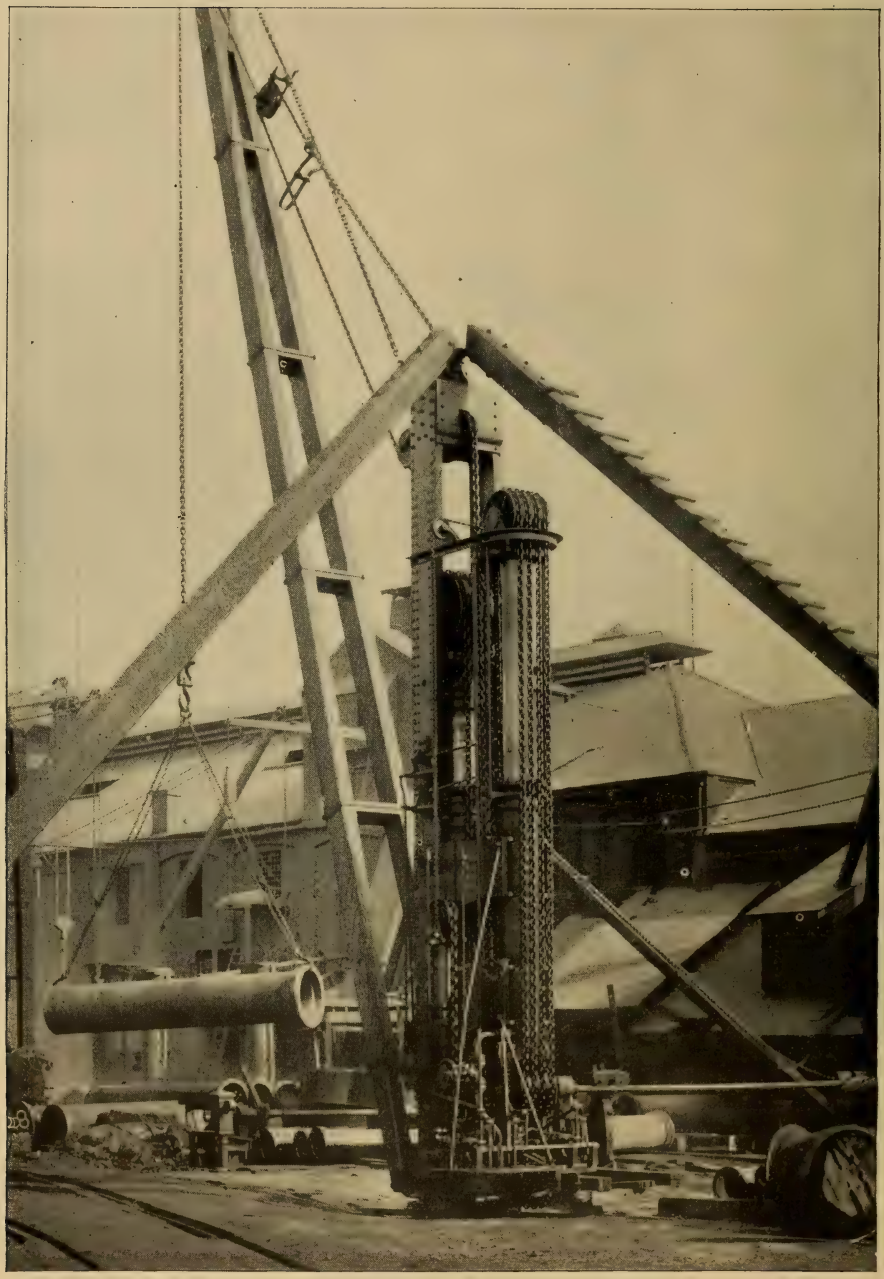
To suit the varying pressures that may be required in different machines operated by the same pressure-water, differential accumulators are designed. The automatic deflecting valve is fitted to allow the water delivered to be returned to the suction tank when the ram is at the top of its stroke. A safety valve is a necessary fitting.

When it is necessary to use higher pressures than those to which the accumulator is charged, an intensifier is employed. This consists of two differential rams in line, of diameters proportioned to the difference in pressure required. The larger ram is hollow, to serve as a cylinder to the smaller ram, and it is the only portion of the mechanism which moves, the larger cylinder and the smaller ram being fixed. Water is admitted at the top of the small ram to the interior of the moving cylinder, forcing the latter down to its lowest position. Water is then admitted to the outside of this cylinder, and so, by acting on its larger area, ejects the water



AN HYDRAULIC FOUNDRY WALL CRANE. ALL MOTIONS BY POWER. MADE BY MESSRS. GLENFIELD & KENNEDY, LTD., KILMARNOCK, SCOTLAND

special feature in these is that provision is made for holding up such of the weights as are not required. This may be done by means of wrought iron bars passing under the weights, the bars being put through holes in the framing, or by other equivalent devices. An automatic stopping and starting gear is fitted to most accumulators to control the movements of the pumps by regulating the steam valve. Sometimes an



AN HYDRAULIC DERRICK CRANE FOR FOUNDRY YARD SERVICE. ALL THE MOTIONS ARE PERFORMED BY HYDRAULIC POWER. MADE BY MESSRS. GLENFIELD & KENNEDY, LTD., KILMARNOCK, SCOTLAND

from the interior of the same at a proportionately increased pressure. A non-return valve prevents the return of this intensified water through the controlling valve. These are the elements of an hydraulic system, whence distributing pipes, rigid or jointed,—walking pipes,—supply the machines.

In both foundry and machine shop one of the most important applications of hydraulic power is in the operation of cranes. For these the steady, solid pressure of power water is admirably adapted. The minute adjustments possible, the direct pull or push, without the intervention of gears, the absence of noise, make water an ideal agent for all cranes of fixed type. A feature of value is that the location of the power cylinder or cylinders may be varied in many ways to suit the design of crane which happens to be most convenient for the work in hand. Water is not suitable for overhead travelling cranes, but in its own sphere it will be hard to beat,—even by electricity. Those who have systematically used hydraulic lifting tackle are generally very strong in its praise.

The immense utilities of the overhead electrical traveller should not be allowed to obscure the merits of the wall cranes, which are really indispensable in any properly equipped foundry. They are also very desirable in machine shops of certain types, such as those which deal with a large volume of massive work, and for the same reason that they are indispensable in foundries, this being that the cranes are engaged for such a great length of time upon each piece of work that an overhead traveller could not possibly serve all the men and machines in a long shop, nor even in one of moderate dimensions. And if the travellers are multiplied sufficiently they may cost more than wall cranes, besides which their movements will sometimes clash. The light overhead tracks are an alternative to wall cranes, but they are not so suitable for heavy loads. Neither do they command a given area entirely, as does a swing crane with a racking carriage.

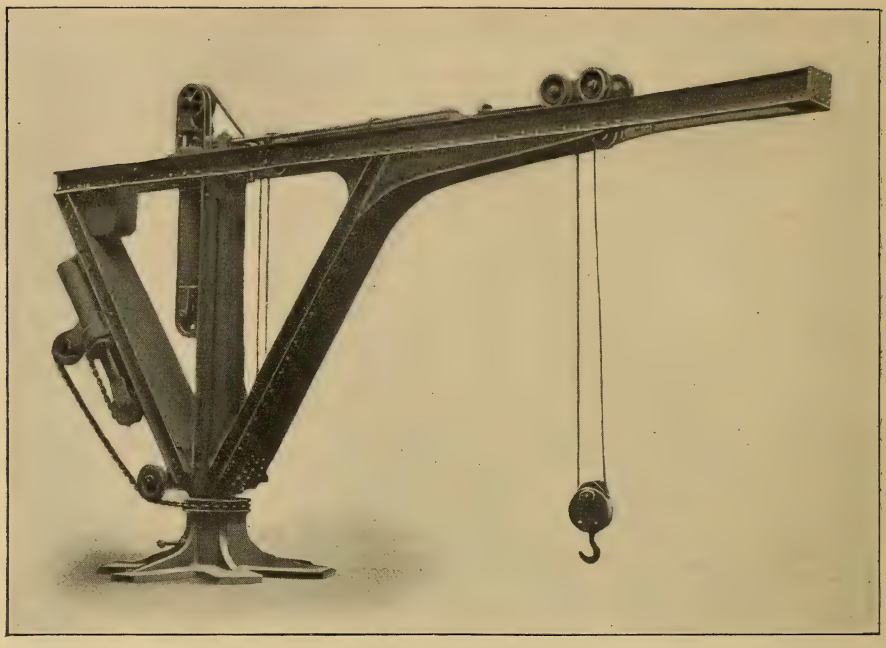
It is in these classes of cranes that hydraulic power has the advantage. The objection to steam cranes in shops is great, no matter whether they are self-contained,—that is, with engine and boiler on the foot-plate,—or whether they are operated by steam brought down through a pipe in the centre of the post. Hand cranes fill a very useful place for light loads, but not for heavy ones in shops where there is much work.

A point that must be emphasised in favour of the hydraulic crane is that the position of the cylinders is quite immaterial, convenience of arrangement and handiness being the only matters to be considered. In the majority of instances the cylinders are all on the crane, but in some designs one or more cylinders are located away from it. Thus, the slewing cylinder may be underground in the foundation work, or it may be attached to the wall above the crane, the turning chain sheave being at the top of the post instead of below, as usual. Lifting cylinders may be attached to the wall instead of to the crane, or, as is the case in one design, where a crane is attached to a shop column pivoting against it, the lifting cylinder may be bolted to the column. And all the valves may be fastened to the wall, the advantage of which is that the crane occupies no more floor space than that covered by the post,—a point which counts for much in any crane that stands out on a foundry floor.

There is hardly another type of crane of which the details are so exceedingly accommodating in character or which takes such protean forms as the hydraulic.

Electricity is the real present rival of hydraulic power for wall cranes; but it involves a considerable amount of reduction gear of high quality which it is desirable to dispense with in foundries, and high speeds are not wanted for the short lifts of wall cranes, though they are most desirable for travelling cranes. From these points of view the hydraulic wall cranes are the most desirable machines to use in foundries and machine shops.

The hydraulic wall cranes occur in so very wide a range of designs and of powers that they cover all possible re-



AN HYDRAULIC CRANE MADE BY MESSRS. HENRY BERRY & CO., LTD., LEEDS, ENGLAND

quirements. They are, speaking generally, better adapted for the service of the foundry and machine shop than the independent or pedestal types of hydraulic cranes, because they leave the floor area entirely unobstructed. This should be recognised as a point of much importance in any department.

In the foundry a clear floor is very desirable for handling moulds to the best advantage, and to secure the best utilisation of the shop area. In the machine shop it is necessary in order that room shall not be blocked, which might be better occupied by machines, and by the pieces of work brought to them. Wall cranes may also be utilised in greater numbers than pedestal cranes, since wall space is of little account, except for hanging up patterns and grids in the foundry and templets in the machine shop. Wall cranes still leave sufficient room for these and other appliances of similar nature.

The place of independent or pedestal cranes in foundries is in squarely built shops, unprovided with an overhead traveller and handling heavy work. An independent crane occupying the centre, supplemented with a few light wall cranes, is the best to employ in such a case. Its radius should be equal to that of the shop, as one of its every-day functions is the lifting of metal from the cupola and pouring it into the heavy moulds. This is not the best type of shop, but there are a considerable number built in this way. Independent cranes are used in oblong shops also, but they are not to be recommended in any scheme of reconstruction, or in new buildings.

In the machine shop a suitable sphere for the independent pillar crane is among the very heavy machines where the massive work handled would put too great a task on wall cranes. Then the location of the crane should be fixed to serve three or four adjacent machines. In any case, however, the crane is an obstruction, and the handling would be better done in such circumstances by an overhead traveller. The fact of a firm having an hydraulic plant in operation would, however, be a strong point in favour of a pillar crane.

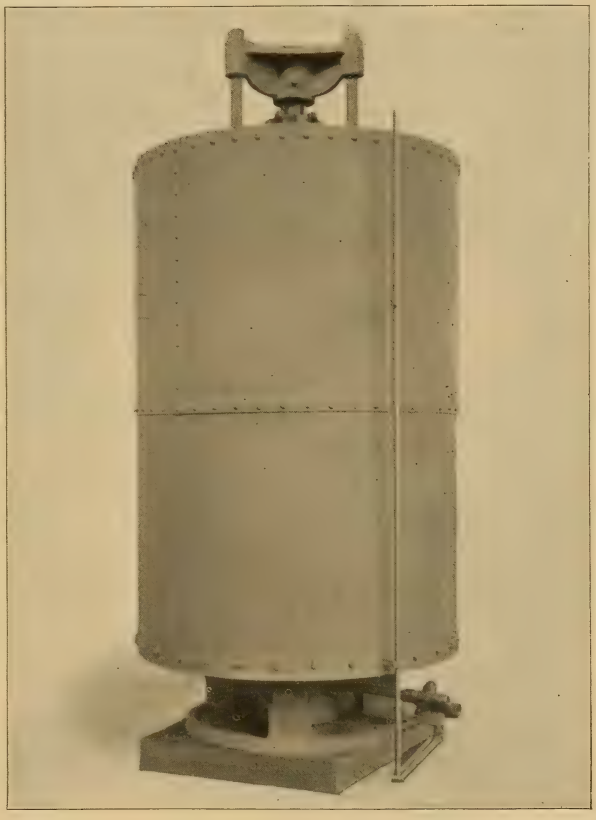
Whatever form of crane is adopted,

whether the wall or the pillar type, an important point in the foundry is to have the swinging cranes within radial touch of one another. This, however, is of lesser value in a shop that is provided with an overhead traveller, but in the absence of the latter the arrangement is necessary. The advantage is seen in turning over boxes, in making heavy lifts with two adjacent cranes in combination, in slinging two ladles for pouring a single mould, in passing heavy ladles and boxes down the shop, from crane to crane, in the absence of tram lines, and generally in handling work over areas that are not entirely covered by the swing of a single crane. The same reasons, modified by the difference in the character of the work done, apply in a lesser degree to the machine shop.

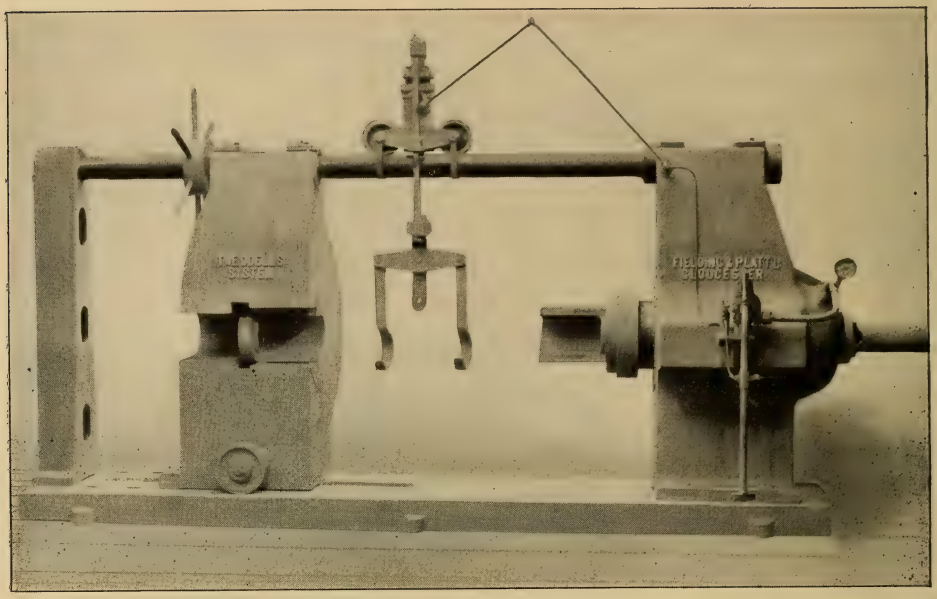
The simplest wall crane is one that is provided with one power movement only, that of the jib and its tie, on the post. The ram or piston-rod may be fixed, and the cylinder be moved up and down under its pressure, carrying the jib and tie, in this case overhead, with it. Rollers, one at the back above and one at the front below, take the pull of the tie and thrust of the jib, and afford the necessary smoothness of motion. The post is swung by hand, pivoting in brackets, bolted to the wall, and the varying radius is provided by a jenny pulled along by hand on the jib. The load, being slung from this, is lifted and lowered in unison with the jib by the moving cylinder.

In another type of wall crane, instead of a direct vertical movement of the jib bodily taking place, the latter remains at a constant height, as in common cranes, and the load is lifted and lowered by chain. The design is thus that of the ordinary crane, having either a single chain lift on a constant radius or a double chain lift on a variable radius, with a racking jenny. The lift is obtained by passing the chain over a fixed pulley, by which device it is lengthened or shortened by the up and down movements of the ram.

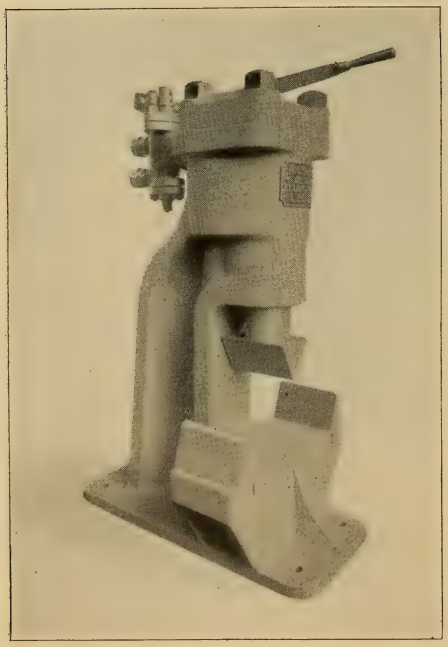
In another broad type of wall crane in which also the jib does not lift, the lifting cylinder is attached to the jenny. The ram carries a chain pulley at its upper end, and its rise and descent lift and lower the hook. Here a walking pipe is necessary to carry the water to the cylinder at its various longitudinal positions on the jibs. In some light



A BOX TYPE ACCUMULATOR MADE BY MESSRS. RICE & CO., LTD., LEEDS, ENGLAND



HYDRAULIC WHEEL PRESS TO TAKE IN WHEELS UP TO 6 FEET IN DIAMETER. THE LEFT HAND STANDARD IS ADJUSTABLE TO SUIT VARIABLE LENGTHS OF SHAFTS OR AXLES. MADE BY MESSRS. FIELDING & PLATT, LTD., GLOUCESTER, ENGLAND



HYDRAULIC PIG IRON BREAKER MADE BY MESSRS. RICE & CO., LTD., LEEDS. THIS IN MANY STEEL WORKS HAS DISPLACED STEAM HAMMERS FORMERLY USED FOR THE SAME PURPOSE

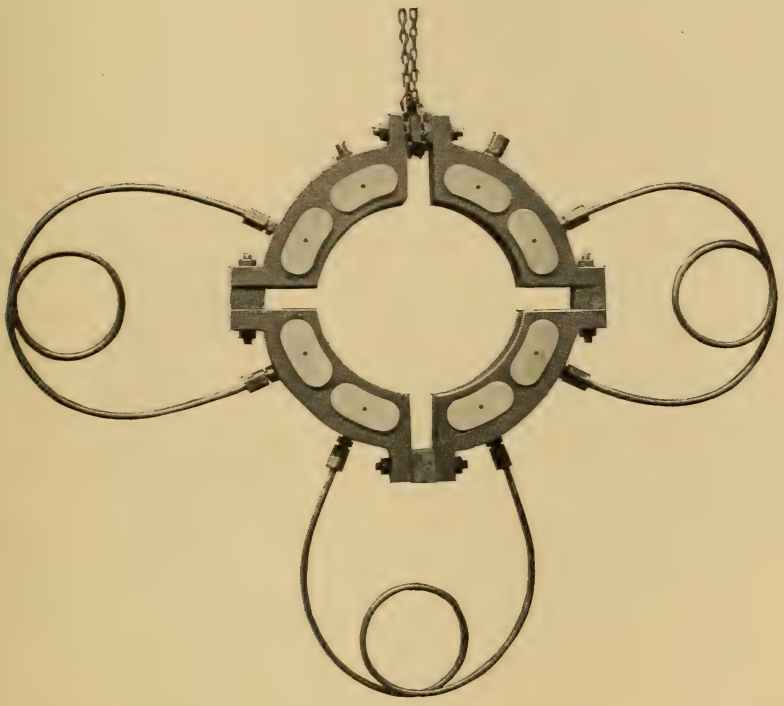
wall cranes the jenny is racked along with an endless chain, as in many hand cranes. The slewing is done by hand, and the cylinder between or on the posts lifts and lowers.

A heavy wall crane, with all its motions power-operated, usually has the footstep pivot bearing on the ground and the upper one against the wall. The hoisting cylinder may be between the post framings, and the racking cylinder also, or alternatively on each side of the jib; the slewing cylinders are generally either on the base or below it, or behind the mast. The general design of the framing is like that of foundry and forge types of plated cranes.

A wall crane need not necessarily be pivoted against a wall. The same crane will serve for wall or column. As in many shops rows of columns separate the bays, these form excellent points of attachment for cranes, in addition to the outer walls. When the columns are built of plates and angles or lattice work, and of rectangular cross-section, they do not afford facilities for the slewing cranes which are attached to them turning round a complete circle. But two

cranes can be pivoted on opposite sides, facing and serving the separate bays. Or if the columns are of cast iron, circular belts may be cast on and turned to receive straps and rollers by which a crane can swivel round a complete circle.

Self-contained or independent hydraulic cranes, fitted with complete movements, differ in design from those which have a pivot support at the top. If the latter can be utilised, the crane is both lightened and simplified. A self-contained crane is a massive affair. It is strutted out at the rear to afford some counterpoise to the jib and its strut, and the base is spread out broadly and secured to massive foundations. The cylinders are differently placed in various designs, but one is usually placed on the hinder strut to help counterbalancing. Sometimes this is the lifting, sometimes the turning cylinder. A jenny is racked along the horizontal jib. Telescopic rams are fitted to many cranes of high power to permit of lifting light loads without waste of water. These differential, or internal and external, rams in some types of cranes give place to separate rams and cylinders in others. In that case two or more distinct cylinders are used for greater or lesser loads, each complete with its own valves, pipes, chains, etc. The chains are carried over separate jib head pulleys, side by side, but also distinct. This, it may be remembered, was the device adopted by Lord Armstrong in the first hydraulic crane he constructed for Newcastle Quay. Three lifting cylinders acted separately or collectively for the maximum power, which was five tons.



SEGMENTAL HYDRAULIC PRESS FOR STARTING SCREW PROPELLERS OFF THEIR SHAFTS.
MADE BY MESSRS. YOUNGS, RYLAND STREET WORKS, BIRMINGHAM, ENGLAND

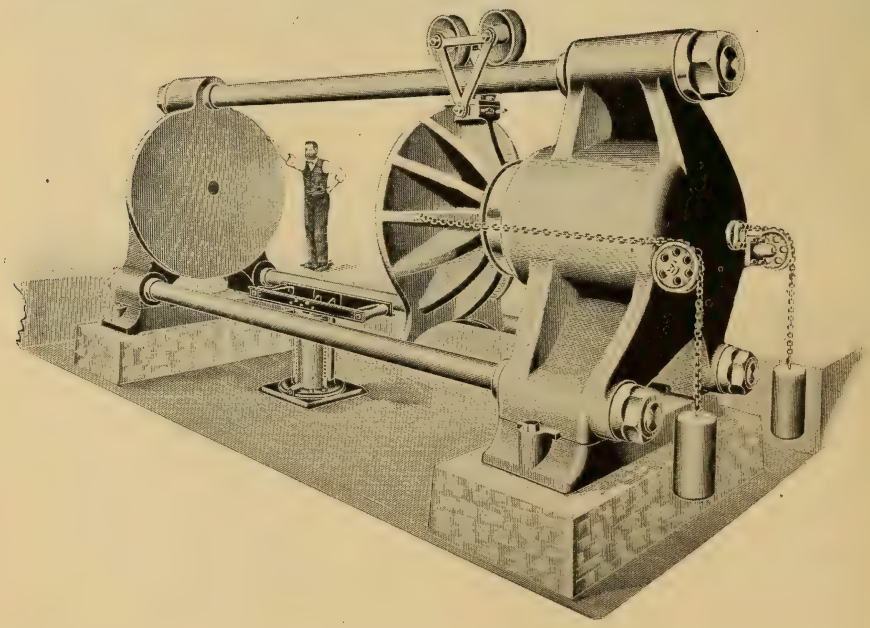
In some self-contained cranes of light powers the lifting cylinder forms, or is stepped into, the centre support, within which the ram lifts the jib bodily with its jenny,—the direct-acting type. Slewing is done by pulling round on the

chain or load. To lessen friction, the jib is properly counterbalanced. An extension of the ram upwards forms the post, standing above the jib, and having tie rods coming down from its top end to support the back and front ends of the jib.

Steel foundries use hydraulic cranes largely for handling ingots, and as water-power is laid down for operating the forging presses, these cranes are the best adapted for this service, more so than electric motor-driven or steam cranes, in which there are many gears, clutches, etc., subject to injury by the dust from the furnaces. The ingot cranes take many forms, and occur in many sizes. A common one is that just noticed, the self-contained and counter-

gears, in hand-crane fashion. Some of these ingot cranes are supported at the top. Then, as the ram lifts the jib, the top of the post is guided by a shaft that slides through a pedestal fixed in a girder in the roof. Heavy, self-contained ingot cranes are made from two or three tons up to twenty tons power. A common application of these in steel works is for the removal of ingots from the soaking pits to the rolling mills. In a good design of this type the slewing cylinder is placed on the hinder strut, and the lifting and racking cylinders are between the posts.

The term "jiggers" is applied to the multiplying type of hydraulic mechanism which is fitted to hoists and lifts. These "jiggers" are almost universal provid-



A 60-INCH HYDRAULIC PIPE-TESTING MACHINE, USED FOR TESTING CAST-IRON WATER PIPE FOR BURSTING. MADE BY THE WATERBURY FARREL FOUNDRY & MACHINE CO., WATERBURY, CONN., U. S. A. THE PIPE TO BE TESTED IS HELD BETWEEN CAST-IRON HEAD AND BASE PLATES WHICH SEAL THE PIPE ENDS, AND WATER IS THEN RUN INTO THE PIPE AND PRESSURE APPLIED

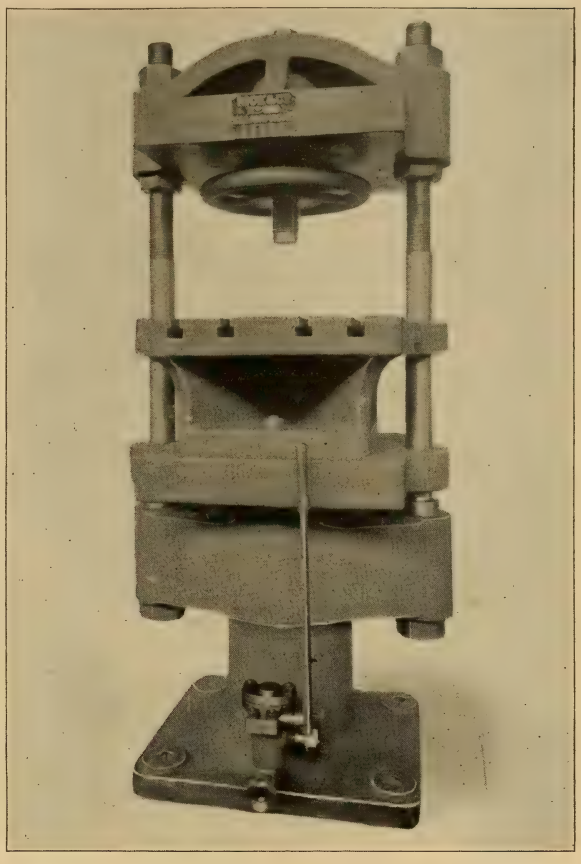
balanced crane of low power, ranging from one ton to two tons. In these the jenny is racked along by hand, and the jib is pulled round in the same fashion. In the higher-powered cranes the racking is done with a dependent chain and

ers of power, being applicable to many kinds of service. They are elastic in character, not only in the fact that they can be located in any position without the slightest sacrifice of efficiency, but also because, by the multiplication of

pulleys, a high lift can be obtained by a short stroke of the ram; and by employing a telescopic arrangement of rams,—a smaller one working within a larger,—the jigger can be made to exert two different powers.

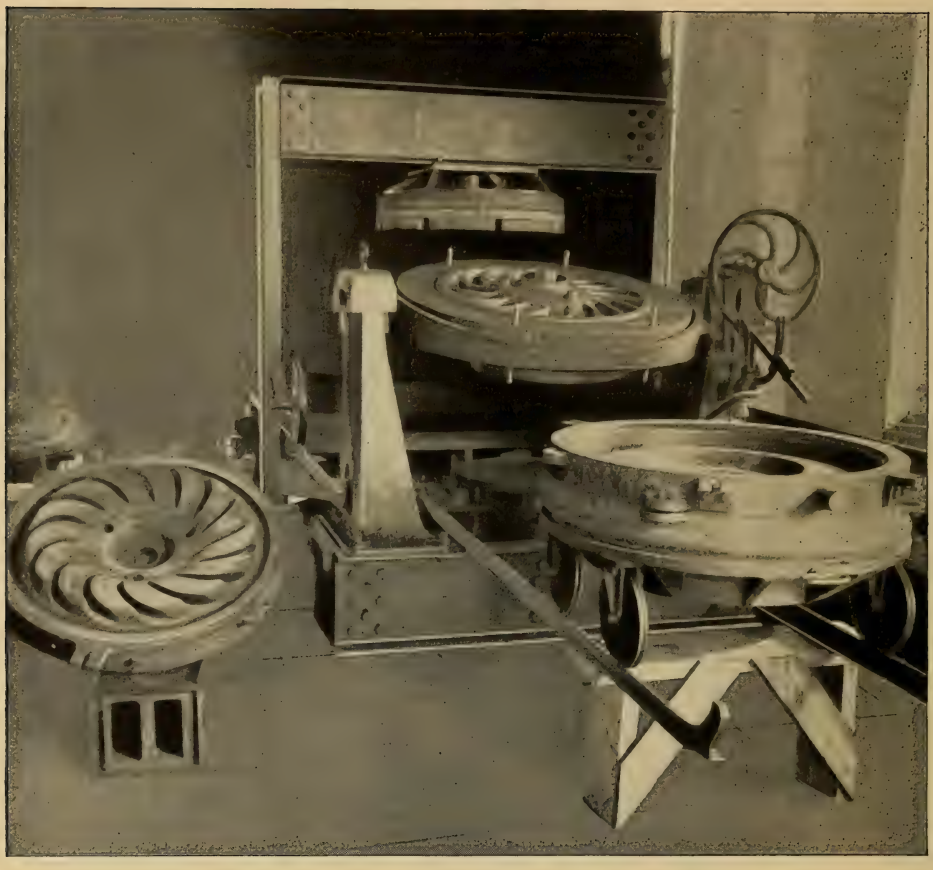
Cupola hoists are operated better hydraulically than by any other agency. They have to be moved through a definite distance only, in a location that is never altered, and the weights of the loads lifted do not vary materially. These hoists are made direct-acting, like the lifts so often used in railway stations, in which the cylinder is sunk in the ground to a depth as great as the height of the lift. In a cupola hoist this is generally from 10 to 15 feet.

The indirect or suspended lift has a short cylinder bolted to the guides at one side or elsewhere, as may be most convenient, and the length of stroke of the ram is multiplied by pulleys over which a wire rope passes to the cage. Of this design there are many modifications, and where hydraulic power is installed it makes a suitable form of lift for storied factories comprising light machine floors for which the conditions are not identical with those in hotels and tall public buildings in which great speed of lift is demanded. Generally, in a storied works the same lift has to serve for the goods and the hands, and solidity more than speed is the quality required. The suspended system must be adopted in such a case, because the maximum height precludes the employment of cylinders sunk in a deep well. In this system the cylinders, though most commonly attached to the guides, may be placed horizontally or diagonally, and at top or bottom, in roof or basement, or at the side in one of the shop floors. The lifting chains or ropes may be led off in any direction. In suspended lifts of large size the weight of the cage is often counterbalanced by means of suspended weights, and an automatic safety device is fitted by which the cage is locked in the event of the parting of the lifting ropes or chains.



SPECIAL MANDREL PRESS FOR DRIFTING OUT SQUARE HOLES. MADE BY MESSRS. RICE & CO., LTD., LEEDS

The hydraulic jack is a little machine which is in constant use in the machine shop for levelling, making adjustments of heavy work, for lifting up massive pieces, for the insertion or removal of packings, of axles, etc., and also for traversing and pushing. The jack principle is embodied in various little mechanisms besides. One is an hydraulic shaft straightener for truing-up shafts before turning them in the lathe. The shaft is inserted through two straps, and the jack presses the shaft upwards



HYDRAULIC MOULDING MACHINE WITH TURN-OVER PLATE, PRODUCING WAGGON WHEEL MOULDS. MADE BY THE BADEN ENGINEERING WORKS, BADEN, GERMANY

against the reaction of the loops of the straps. The advantage of such pressure over hammer-straightening is that the press does not simply compress the fibres locally as hammering does, and the shaft is, therefore, less likely to spring back after a rough cut has removed the compressed fibres. The power required to operate a screw-driven shaft straightener is also trying to the operator, as compared with that necessary for an hydraulic straightener. A special adaptation of the jack is that for forcing bolts out of the couplings of screw shafts and for similar heavy work, thus avoiding the use of sledges and the burring over of the bolt tails which accompanies their employment.

The increasing use of gauges, especially those of the limit kind, has given a new name to a class of work,—"press fits,"—otherwise termed driving fits, after the method commonly adopted of driving shafts, mandrels and pins into or out of their holes. These are frequently effected with a sledge hammer, with a lump of lead intervening to prevent bruising the mandrel or shaft; or a lead or a copper hammer is used for the purpose. It is well that these rough, uncertain methods should be lessening in favour of hydraulic presses. Small presses are, however, frequently operated by a lever direct, drawing down a rack-actuated plunger, or screw pressure is employed, with gain of power by gearing, in the larger sizes.

Locomotive and waggon shops must

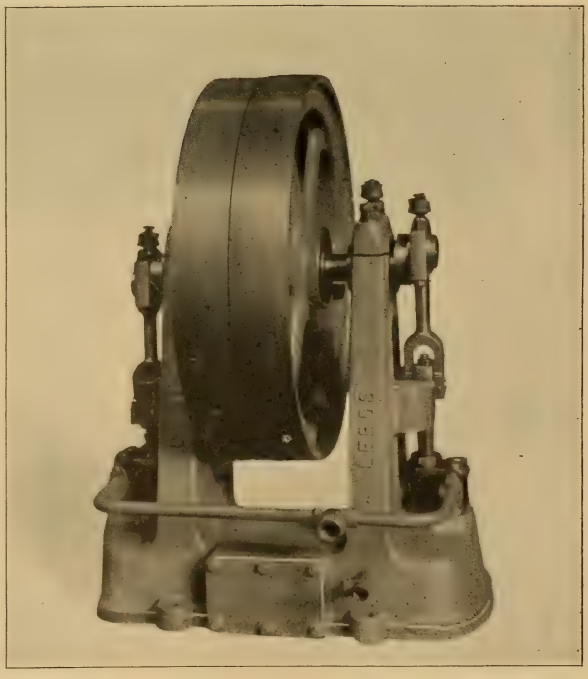
possess an hydraulic plant quite apart from that required for the boiler department. One indispensable application of water-power lies in the various presses for wheels and axles. These are used for pressing wheels on and off their axles, and their steady movement cannot be surpassed. These machines are made to suit wheels of a certain maximum length of axle and distance between tie-bars, and to take wheels of a given diameter. The operating parts, —the cylinder and ram, pumps, water tank, gauge, etc.,—are carried on one post fixed to the base. The axle is slung between this post and another, which is movable along the base, and set with keys to tie-bars. The pump is often of a double-plunger type, making alternate strokes with larger and smaller plungers, but independent, so that one can be disconnected from the other. The advantage of this consists in the use of the small plunger for finally setting a wheel, or the application of a maximum power for the removal of wheels. The pumps are driven by belting from the line shafts of the shop. Frequently also the presses are driven from an accumulator, so doing away with the separate pumps on the machines. Another valuable application of the pressure of water is in taking crane barrels or drums off their shafts,—a device superior to the sledge-driving so commonly employed.

A special tool, allied to the wheel press, and often forming a combination with it, is the crank-pin press, used for forcing in and removing the crank-pins of locomotive wheels. The ram cylinder has a vertical adjustment, to avoid the use of blocking when bringing the press up to the height of the crank-pin.

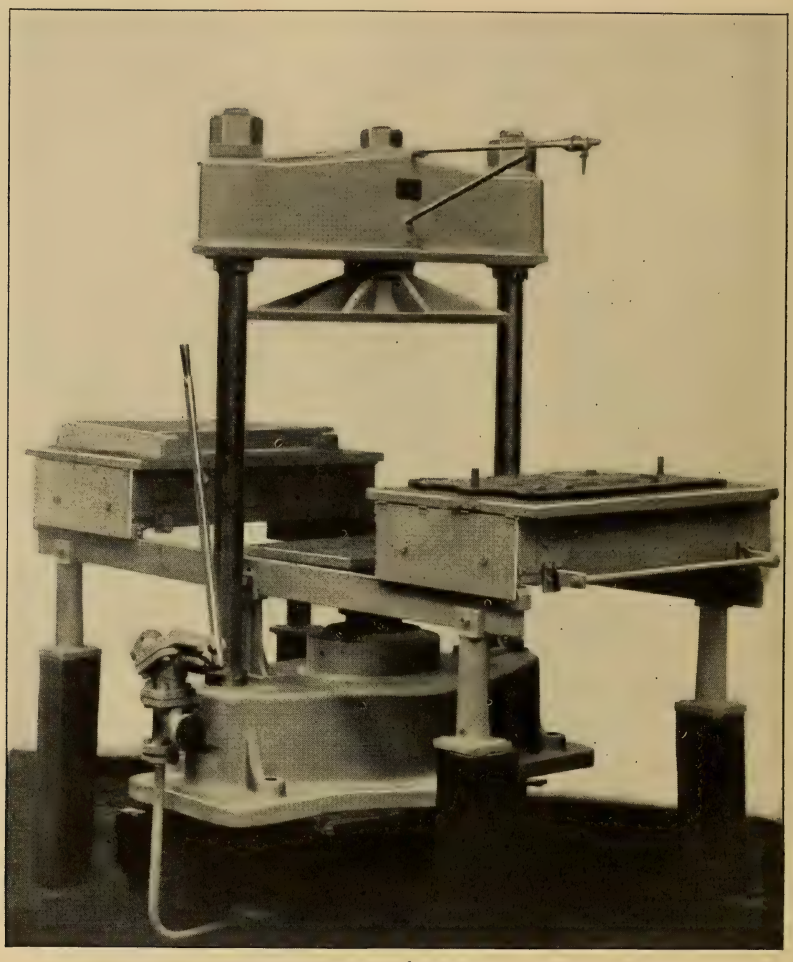
A novel mechanism, shown on page 239, is an hydraulic propeller starter, designed to supersede the usual method of removal by means of wedges, or the warming of the boss by means of a fire. The starter encircles the shaft and presses the propeller boss by means of four segmental rams, working in segmental cylinders. A hand pump supplies the power, transmitted through copper pipes.

Not the least valuable of the applications of hydraulic power in the machine shop is that of the hydraulic pressure pumps, which are operated by hand and are used for making tests of the strength of hollow castings, such as pump casings, pipes, and other parts of mechanism that are subject to great pressures, of from 2000 to 5000 pounds per square inch.

In the work of machine moulding, hydraulic power is certain to occupy a larger place than it has hitherto. Hydraulic machines were in use in a few shops many years ago. Water is still the best agency available for the larger power-operated machines,—superior to



A CONVENIENT FORM OF HYDRAULIC PULLEY PUMP FOR WORKING HYDRAULIC TOOLS



HYDRAULIC MOULDING MACHINE WITH TWO MOVABLE CARRIAGES. MADE BY THE GRITZNER MASCHINENFABRIK, DURLACH, GERMANY

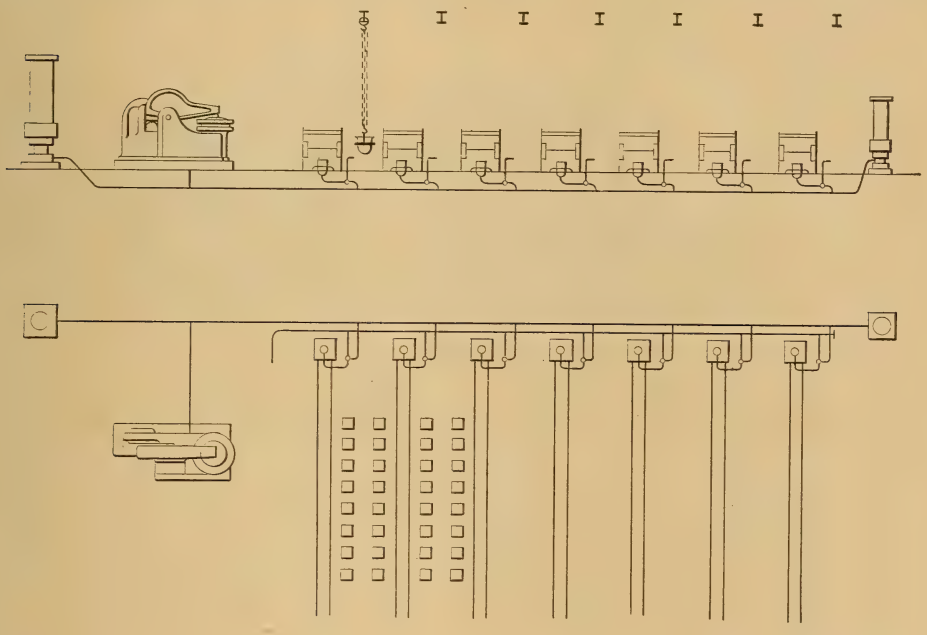
steam or compressed air. It is not surprising, therefore, that its employment is increasing rapidly along with the growth in the size of moulding machines. One of the most remarkable facts in connection with recent practice is this great increase in the size of moulds thus produced. Firms who make hand machines have done very creditably in the designs of levers, in counterbalancing parts, etc., to lessen the labour of turning over and withdrawing heavy moulds; but a limit to the hand power that can be economically applied has come and has been passed in the biggest machines.

The matters involved here are not alone the act of turning over, or of withdrawing, but also in many cases the pressing of the sand, notably in shallow moulds. Hand-ramming,—necessary in deep moulds having irregular faces,—involves a waste of time in many shallow moulds, and also in some of those of even moderate depth. Hydraulic power is an ideal agent here, the water pressure being absolutely steady, free from the concussions which are liable to induce fracture of sand, and being entirely controllable. It is rather remarkable that the advantages of water pressure for machine moulding have not been more

greatly recognised than they are. With very few exceptions, the hydraulic machines in use are mostly found in firms that make them for their own service.

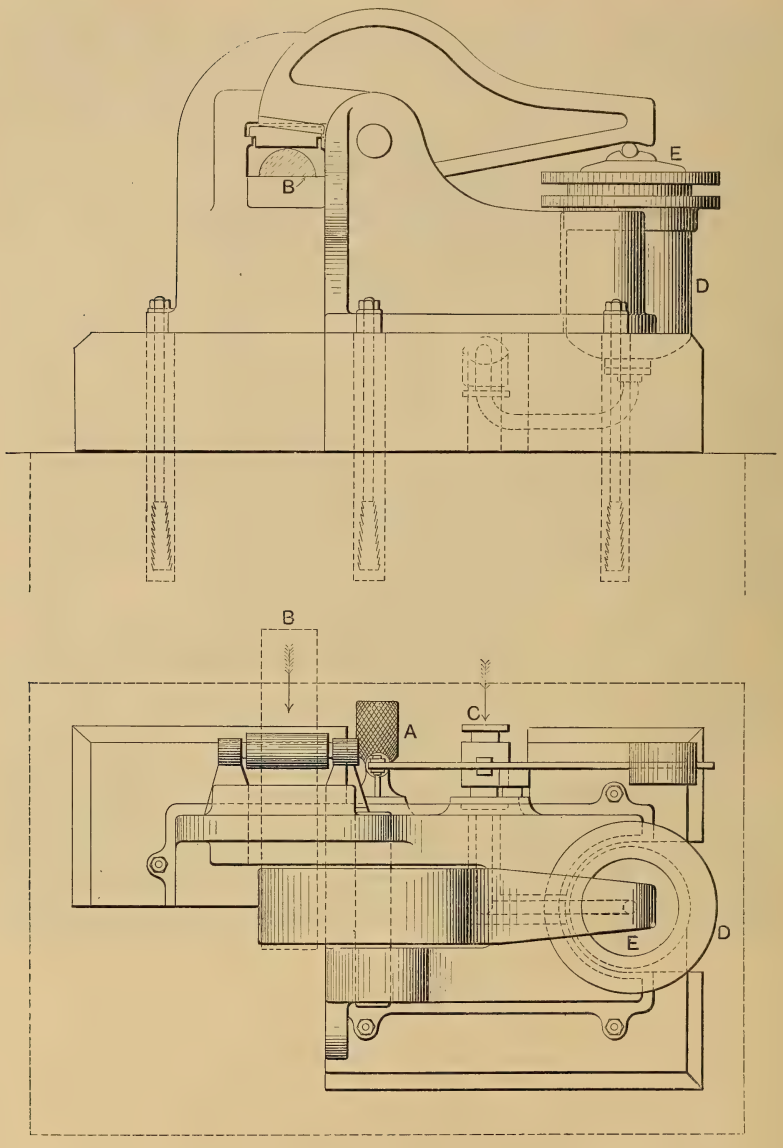
In Germany a great development is going on in this field. Big machines are being made in a number of designs for operation by hydraulic power. It is a movement in the right direction, because it opens out practically unlimited further developments in the size of machines, which is the direction in which the possibilities of improvement lie open to designers. Of small machines there are an enormous number, but the field is still but sparsely occupied with those for massive work. There is no good reason why the biggest patterns, as well as the smallest, should not be put on machines. That they have not been so arranged is because manufacturers have not investigated the question of designs suitable for massive machine moulding. Hydraulic power is the agency by which this problem is being solved.

German designs of moulding machines may be divided into several groups, so extensively has differentiation proceeded. A favourite form of heavy machine, and typical of a large number of German designs, is that in which rail tracks are extended either in front of or to right and left of the machine proper, so that work may be run along under for pressing, and away for closing. This general design is modified in many details. In one broad type the pressing is done by an hydraulic ram beneath, but the pattern is withdrawn by a hand lever. In another, lifting rams are provided for the withdrawal of the pattern. The ram and presser head are connected by vertical pillars situated midway between the ways that carry the two travelling platforms with the patterns and the boxes. These, while away from the press, are filled with sand, and then run, in turn, under the press, squeezed, and the pattern is drawn. The boxes are then taken away and closed.



ARRANGEMENT OF MOULDING MACHINES, WITH RAILS FOR BOXES AND OVERHEAD TRUCKS FOR METAL, IN THE FOUNDRY OF MESSRS. BOPP & REUTHER, MANNHEIM, GERMANY

These machines are designed with various objects, one being to avoid the hinging of the top presser board, which is a common feature in many machines;

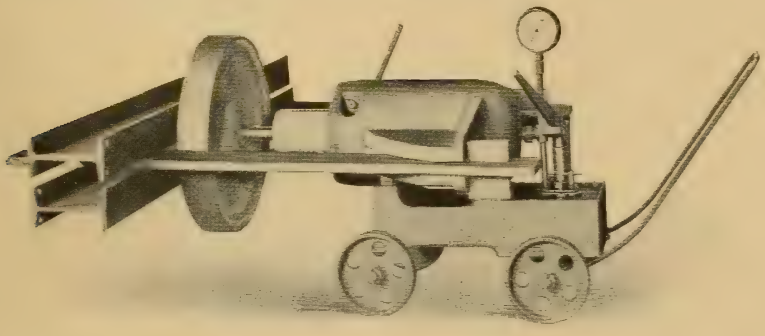


ENLARGED VIEW OF THE HYDRAULIC PIG IRON BREAKER SHOWN IN THE PLAN ON PAGE 245

another is to enable from two to four men to operate one machine. When four men are working at once, two are filling and pressing and two are removing and closing the boxes. Only one ram is used, and one volume of pressure water. Another object is to permit the use of a crane to lift the boxes away after ramming, —a necessary aid when much of the work done is of a massive character.

In several machines the turn-over pattern plate is embodied, the trunnion bearings of this being carried in brackets that slide on pillars supported by the base and cross-head. In a simple case of moulding a divided pattern, the halves of the latter are mounted on the turn-

over plate, and the two box parts are set, one over the top part of the pattern on the plate, the other on the travelling waggon below. The top one is filled with sand, the ram pushed up, consolidating it, a shallow frame, of course, being used to hold the surplus sand. The boxes, which are dowelled, are then clamped together. Then the ram sinks, the turn-over plate following, the plate is revolved, bringing the rammed box lowermost and the unrammed one uppermost, which is then filled and pressed. The clamps are released, the ram is lowered, and as the turn-over plate is arrested in its descent by collars on the pillars, the lower box falls away from the pattern, and, resting on the



PORTABLE HYDRAULIC PRESS FOR PRESSING ON OR OFF CRANKS, CAR WHEELS, COUPLINGS, ETC. MADE BY THE CHAS. F. ELMES ENGINEERING WORKS, CHICAGO, U. S. A.

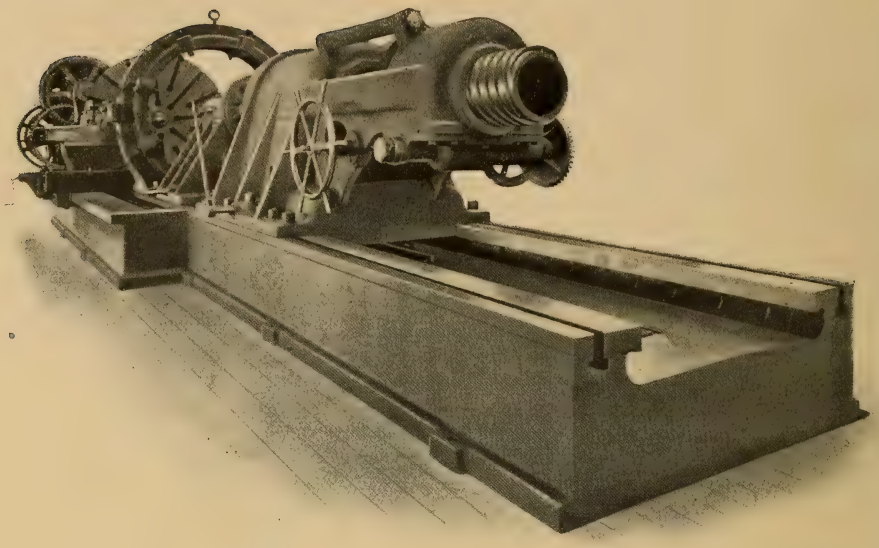
waggon, is run away. The plate is turned over, another box part clamped and pressed, and again the ram descends; and so the process of pressing and withdrawing box parts alternates.

In the smaller machines the table is turned over by hand; in those of large dimensions, spur or worm gears are fitted,—a necessity when boxes measure from 4 feet to 9 feet across. Two press cylinders are often fitted in the big machines in place of one. The presser head, instead of being swung over the box, is travelled on a waggon, and, as in some other machines, and in cranes, a device is employed for economising the pressure water. Machines such as these are used for moulding locomotive and waggon wheels, the frames for textile machinery, rolling mill standards, etc.

The hydraulic press is applied in Germany to the multiple system of moulding. This system is applicable to shallow patterns only, which can be moulded by simple pressure of the patterns into the boxes of sand. The lower half is pressed directly into the box, and the top half into a frame that drops within the box. Two half moulds, with their runners, are produced at one squeeze, and these are superimposed for the multiple pouring. To a certain extent this system will prove a rival to the snap flasks. Both are specially adapted to shallow work, not exceeding the capacity of from 18 to 24-inch boxes. While the use of snap flasks affords economy in boxes, the naked moulds being put on the floor, the multiple system, while requiring flasks, economises floor space vastly, due to the superposition of the boxes. Both of these economies become of increasing importance in the face of the enormous daily output of the later designs of moulding machines.

In a machine designed for ramming both halves of a shallow mould at once, the waggon device on rails is employed to carry the pattern plate along, and the ram is utilised to close the moulds, thus:—

The pattern plate, having halves on opposite sides, and carried on the waggon, is run between the half boxes when widely separated. The movement of



A 100-INCH BORING AND CUTTING-OFF LATHE WITH HYDRAULIC FEED FOR THE BORING BENCH. THE BORING BAR IS CARRIED BY A HOLLOW PISTON IN AN HYDRAULIC CYLINDER WHICH SUPPLIES THE NECESSARY END PRESSURE. MADE BY THE NILES-BEMENT-POND CO., NEW YORK

the ram presses the boxes against the reaction of the press board, which also is carried on wheels. The lowering of the ram draws the bottom box away, and simultaneously, through the medium of cords over pulleys, lifts off the top box. Then the pattern plate is run out of the way, and the ram is again utilised to close the boxes ready for pouring.

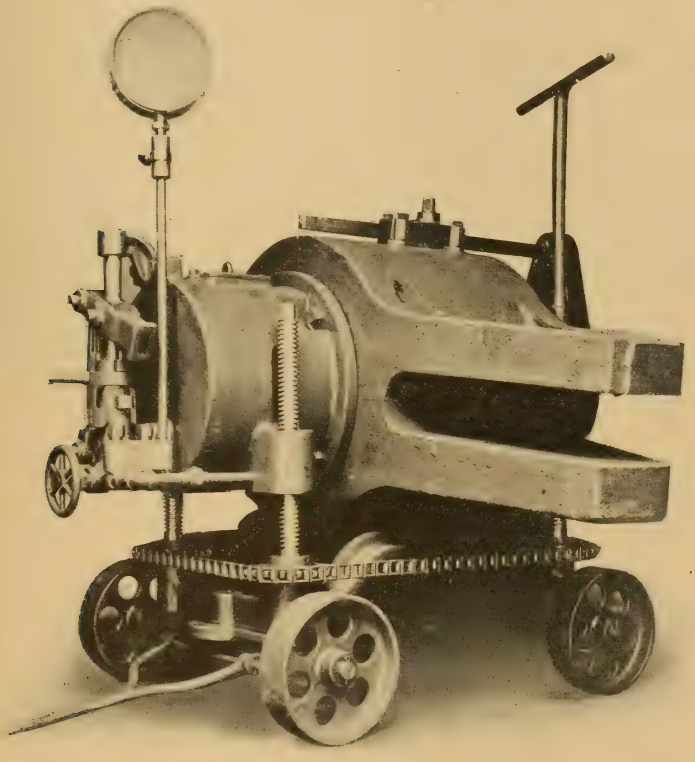
A rather large class of hydraulic moulding machines is made in which the mould is pushed out of the frame in which it has been pressed, and is then ready for pouring, without encircling flasks. In this respect the moulds are like those made in snap flasks, but deeper moulds can be produced in this way than with snaps. In this class of machine both portions of the mould are pressed by one movement of the ram, then moved apart, the pattern plate swung aside, and the ram again lifted to close the mould, which is finally pushed out of the frame.

Nor is the deeper class of work unprovided for. In fact, it is rather remarkable to note what deep moulds are now produced by pressing alone,—work which would generally be considered more suitable for detailed hand ramming. The explanation must lie in the steadiness of the pressure communicated throughout the whole body of sand. It is certain that the application of hydraulic power is fraught with great promise in the development of the more massive forms of moulding machines.

Messrs. Bopp & Reuther, of Mannheim, who are large manufacturers of foundry appliances, have an installation of over ninety hydraulic machines in their foundry in which they produce a large quantity of valves and fittings. A plan of a portion of this plant is shown on page 245. The machines are ranged down the sides of the shops. Tracks to slide the boxes along lead away from the machines, whence they are picked off, closed, and placed in the spaces between the rails for pouring. A similar arrangement exists in the foundry of the Great Western Railway shops at Swindon, and in others. The machine shown at the left of the diagram is an hydraulic pig breaker.

This is further illustrated on page

246. The flow of water is controlled by a treadle *A* close by the workman, who thrusts the pig *B* through the machine. The treadle controls the valve *C*; *D* is the cylinder, and *E* the top of the ram. The illustration shows a fixed machine. But it is also made portable, to be run on rails over a foundry bin, adjacent to the railway delivery truck. The man takes the pig from the latter, and, as it is broken, it falls into the bin, to be handed into the cupola, as required.



HYDRAULIC CRANK PIN PRESS MADE BY THE WATSON-STILLMAN CO., NEW YORK

A somewhat similar design of machine is adapted to steel foundries for breaking up old tires.

The practice of core making is now also being invaded by the moulding machine. Plain round cores of small dimensions have been made by mechanism for many years past, but recent machines have been designed for producing green sand cores of irregular shapes, and of both small and large dimensions, by hydraulic pressure. The interesting feature in the core boxes used is that the superfluous sand is squeezed out into recesses that surround the core box proper. The analogy between this and the similar recesses or chamfers that surround many dies used for stamping forgings will be noted. Another novel form of hydraulic pressure application is seen in a certain class of machine employed for closing moulds after they leave the moulding machine.

If hydraulic power be compared with the two newer and more popular agencies, air and electricity, the conclusion reached is that pressure-water holds a place which is unassailable in certain spheres, as the other two agencies also do. Compressed air is not to be

recommended either for heavy cranes or for heavy moulding machines, but for the light suspended hoists, for light wall cranes, and for the smaller moulding machines it is more economical and handy than water-power. It is more economical, because the compressing plant costs less than the hydraulic, and occupies less room, and because air costs nothing, while water supply frequently does cost something. It is more handy, because quicker in action, and its transmission to hoists and machines is more flexible than water.

Electricity is not to be compared to water in some classes of heavy cranes, or in hoists; and the application of electric motors to moulding machines would be rather an absurdity, considering the small amount of movement which is required, for which either hand or some fluid pressure is the only suitable method. For this reason hydraulic pressure is likely to hold its own, and this applies to all machines in which heavy direct pressures have to be obtained.

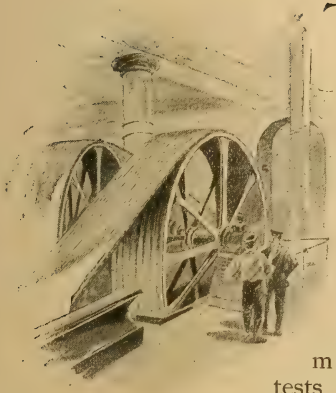
To a considerable extent, doubtless, the choice of an agent must often be determined by the plant existing in a works or in a foundry. A firm that has a plant of a certain kind laid down will naturally try to adapt new machinery to the power-drive already on hand. That, probably more than any other, fact has been detrimental to the more extensive utilisation of hydraulic power. The accumulator is a big and clumsy device. The difficulties of transmitting water at a pressure of, say, 750 or 1500 pounds per square inch through jointed pipes are sufficient to prevent many firms from laying down a hydraulic plant after they have been accustomed to some other form of power. But where water-power is already in existence and understood and worked properly, the hydraulic machines are, and will continue to be, highly appreciated.

SUPERHEATED STEAM FOR STEAM ENGINES

WITH SOME DATA OF THE SCHMIDT SYSTEM

A Posthumous Contribution

By Bryan Donkin

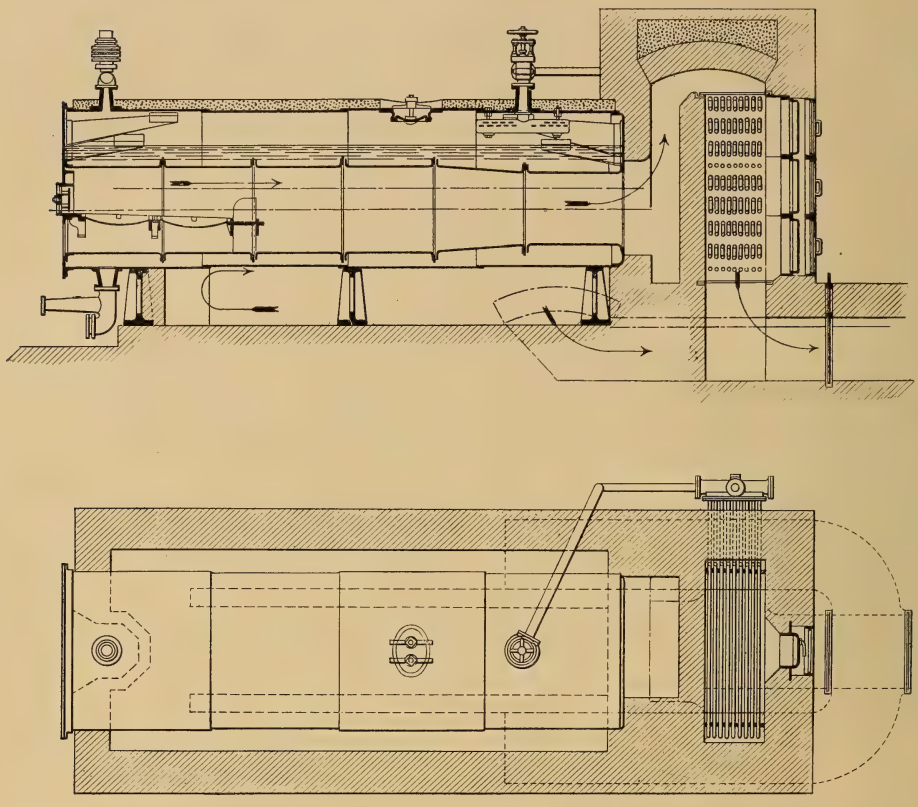


THIS important question of superheated steam has lately been discussed in the Mechanical Section of the Glasgow Congress; several papers were read on the subject, and mention was made of many mechanical tests and experiments. These, however, were mostly based on experience in continental Europe. Mill owners and other employers of industry abroad are more willing to try new proposals and economical methods than those in Great Britain, where novel scientific applications do not progress at all rapidly.

Our conservative steam users are much afraid of introducing a new system of hotter steam into their steam pipes and old cylinders, and this, notwithstanding the fact, proved by repeated experiments, that the more uneconomical, old fashioned single-cylinder engines, in which the greatest condensation takes place, always give the highest advantage with superheated as against saturated steam. The more economical the engine, the less the gain obtained by superheating the steam. British steam engine owners do not believe in this pronounced economy of fifteen per cent. to thirty per cent., and they frequently have a horror of inventors, novelties and innovations. They prefer that other people should make experiments, and they will adopt new methods only after they have proved successful, although of course some one must begin.

The percentage of economy obtained is often difficult to prove exactly, because careful experiments must be made, both before and after the change is effected. The expense necessarily incurred for tests and measurements of coal and water, taking the temperature of the steam, and observing many other points, is generally disliked and objeeted to. How seldom steam users will consent even to measure and record daily the weight of coal and water used, and how difficult it is to make them see the great importance of such data until some of their neighbours undertake to collect them, the writer can testify from personal experience.

Yet these details, which are so easily obtained,—the coal by weighing, the water by gauging it in the best type of piston water meter,—always lead to economy. To them should be added a knowledge of the cost of fuel per thousand gallons of water evaporated, and converted either into saturated or superheated steam, with different priced fuels. Even with all the economic advantages of superheated steam, the heat efficiency of steam engines using it, compares unfavourably with that of the best gas or oil engines. Therefore, when it is a question of a new motive power giving the maximum economy, not only should gas engines working with producer gas be carefully considered on their own merits, but we must also remember that no difficulty is experienced



FIGS. 1 AND 2.—THE SCHMIDT SUPERHEATER,—FLUE-FIRED,—APPLIED BEHIND A CORNISH BOILER

in driving them with much hotter gases than superheated steam.

Some large and well-managed electric light and power stations regularly measure the water evaporated in all their boilers. All the fuel is often daily weighed, and they find themselves ultimately well repaid for their trouble. A few have adopted superheated steam. The apparatus is placed in or about the boilers, and the saturated or wet steam is heated in small pipes by means of the hot boiler gases. In some mills direct-fired superheaters are used with separate fires, or in a battery of small pipes, an inch or two inches in diameter, into which saturated steam from the ordinary boiler is admitted. The chief difficulty is to regulate the temperature of the superheated steam and of the fire.

There was an example of this type of superheater in the boiler house of the Glasgow Exhibition, and at the Paris Exhibition of 1900 many were shown, some at work. The apparatus is similar to a water-tube boiler with small tubes, but instead of water in the pipes, only saturated steam passes into them, coming direct from a steam boiler of the usual type. Some kinds of water-tube boiler in which the hot gases circulate in pipes above the water line, deliver superheated steam direct. This system is much more used and appreciated on the European continent than in Great Britain, and as employed in some of the Berlin electric stations of from 1000 to 2000 H. P., it is found to give considerable economy without much trouble; but the steam is not very highly superheated.

It is well to remember that superheated steam has not only first to be produced economically, but, further, to

be properly and profitably utilised. If very hot steam is used, steam engines must be specially arranged to receive it. Valves, stuffing boxes, and piston rings require careful attention, to prevent undue wear or trouble when using such a hot gas. They should be well lubricated; but there is little difficulty under this head, if the best mineral oil be used. In Germany experiments have been made, showing the decreasing strength of various bronzes at high temperatures. Bronze cannot be safely used with superheated steam at temperatures above 570° F. For the same reason gun metal and copper should be avoided; nothing is so suitable as steel for the steam pipes.

In piston-less or rotary steam engines of the Parsons or De Laval turbine type, no lubrication is necessary in the cylinders. The advantage and economy thus furnished with superheated steam, especially when working condensing, are great, but care should be taken to obtain the maximum possible vacuum. At Blackpool a Parsons turbine is running well and economically with slightly superheated steam.

To avoid difficulties, piston engines worked with highly superheated steam are often made single-acting. Good Corliss valves will generally stand steam superheated up to about 400° or 450° F. without difficulty, but large, flat valves are apt to give trouble. Piston and lift valves seem to work best. Professor Goodman considers that for every 90° F. of superheat, about ten per cent. economy is, within certain limits, obtained with piston engines. Parsons'

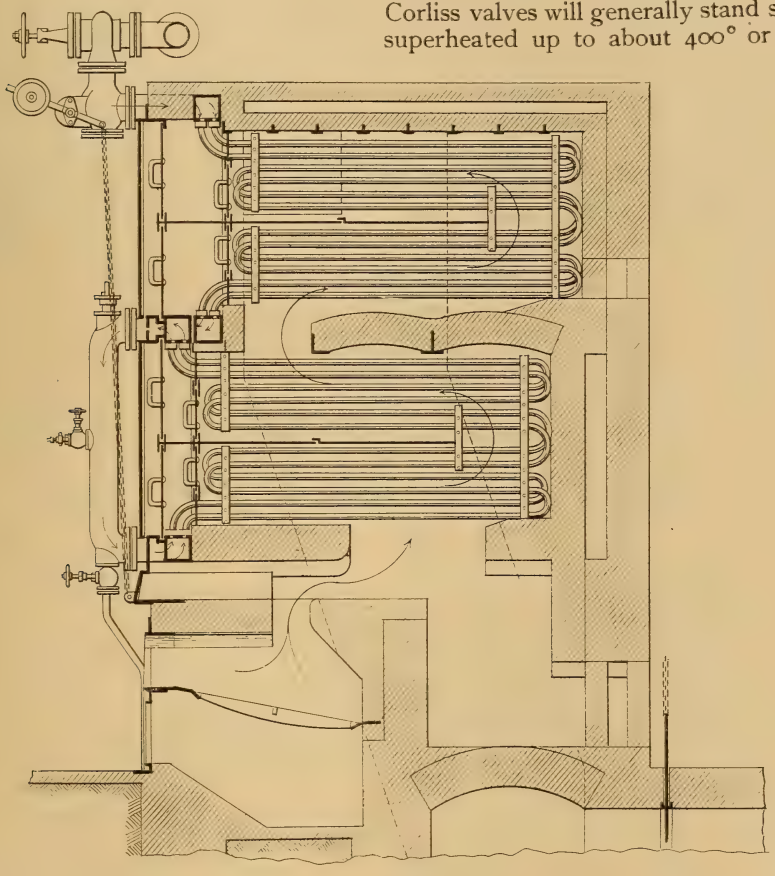


FIG. 3.—A DIRECT-FIRED TYPE

experiments show a gain of twelve per cent. economy with piston-less engines, with about 99° F. of superheat.

Superheated steam has a much larger volume per pound than saturated steam.

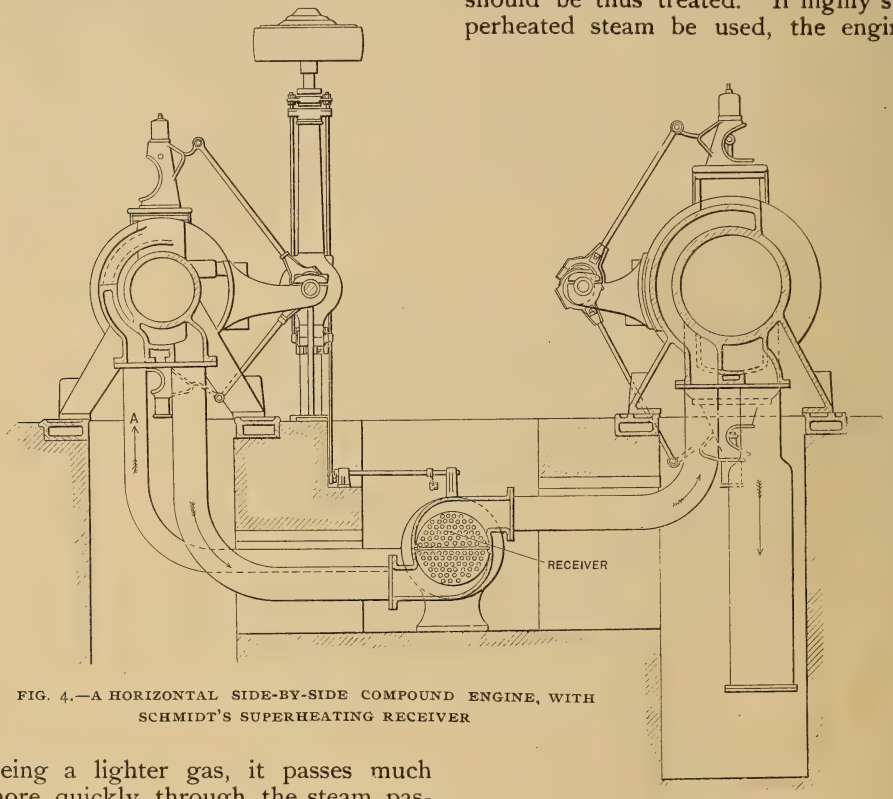


FIG. 4.—A HORIZONTAL SIDE-BY-SIDE COMPOUND ENGINE, WITH SCHMIDT'S SUPERHEATING RECEIVER

Being a lighter gas, it passes much more quickly through the steam passages and valves into any cylinder, and this is an advantage where such passages have a small area. Superheated steam acts like a permanent gas, and does not condense until all the superheat has been given up to the internal surfaces of the cylinders, pistons and other parts. Generally at the end of the stroke in the high-pressure cylinder, all the superheat has left the steam, and it is only dry steam which goes into the low-pressure cylinder.

Sometimes superheated steam is also used between the two cylinders of a compound engine, the steam being passed through a reheater, or nest of pipes, like a surface condenser, thus putting heat into the steam before it passes to the low-pressure cylinder. All pipes should be well covered. It is not, however, usual to jacket the cylinders with superheated steam, and if it is done at all, and no reheater is used, the low and not the high-pressure cylinder should be thus treated. If highly superheated steam be used, the engine should be made specially for it, but for 120 to about 212° F. of superheat, many engineers consider no change of structure necessary.

Experience has shown that where superheated steam is employed, there is little or no practical advantage in working with three cylinders, or triple expansion, as excellent results are obtained with the compound or two-cylinder type. The saving is sometimes lower and sometimes higher; much depends upon the engine, the degree of superheat, and other details. The economy due to the use of superheated steam varies from twenty per cent. to thirty per cent.; in other words the weight of steam required per unit of power is from twenty to thirty per cent.

less than with saturated steam. Thus, smaller boilers can be used, and the first cost of a new installation is reduced in existing plants, or the boilers need not be so much forced.

In comparing experiments with superheated and saturated steam, it is incorrect to take the pounds of steam per indicated horse-power per hour in each case, as the former contains more heat per pound than saturated steam, and allowance must be made for such excess of heat. A well-known firm at Nürnberg, Germany, generally guarantees about thirty per cent. economy of steam, with steam superheated up to about 752° F. This means a saving in coal of about one-third. Last year they put up about two hundred superheaters, consisting of batteries of small tubes. With a less degree of superheat from ten per cent. to twenty per cent. economy of steam or coal may be realised, as shown by reliable test. Most of the leading firms making water tube boilers with the large type of tubes, place the steam superheating apparatus at the tops of their boilers, and many are in use with boilers of the Babcock & Wilcox, Steinmüller, Dürr, and other types. W. Schmidt, a German engineer, has for many years past made a special study of the production and utilisation of highly superheated steam. He uses a small cluster of iron or steel pipes, and places them behind or above Cornish or Lancashire boilers. Examples of this are given in Figs. 1 2, 8, 9 and 10. The hot gases passing around the pipes transmit their heat to the saturated steam in the pipes, and raise its temperature. His system has been applied to many boiler plants on the Continent, but it is little known as yet in Great Britain, although the results obtained show a great economy.* He has also introduced a special separately fired superheater, as shown in Fig. 3.

M. Schwoerer in Alsace has brought out another type, made of cast iron pipes, with ribs cast on both externally and internally, but the writer much prefers small steel or wrought iron pipes to larger ones of cast iron for superheating, and considers them safer. A large

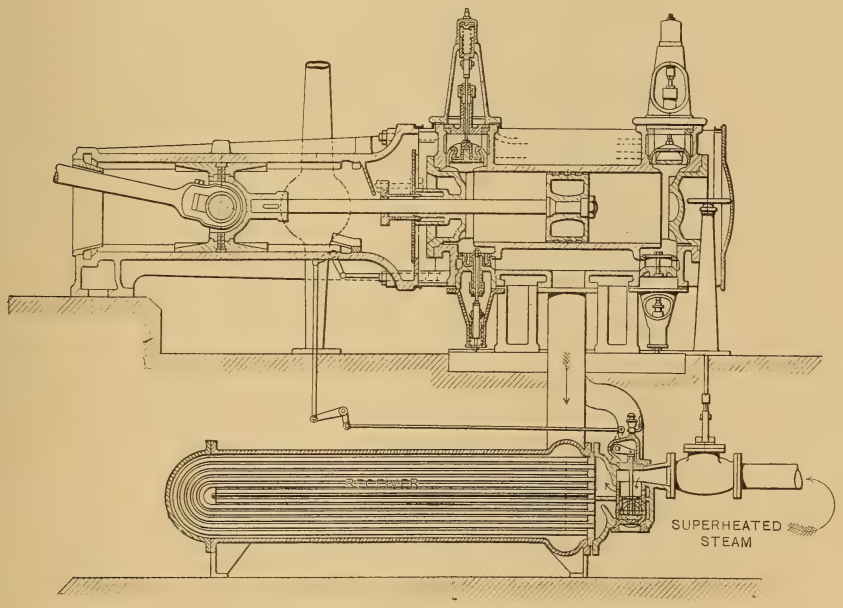


FIG. 5.—SECTIONAL ELEVATION OF THE ENGINE SHOWN OPPOSITE

* Since Mr. Donkin's article was written important progress has been made by Messrs. Easton & Co., Ltd., of London, in developing the use of the Schmidt system in Great Britain, and a large num

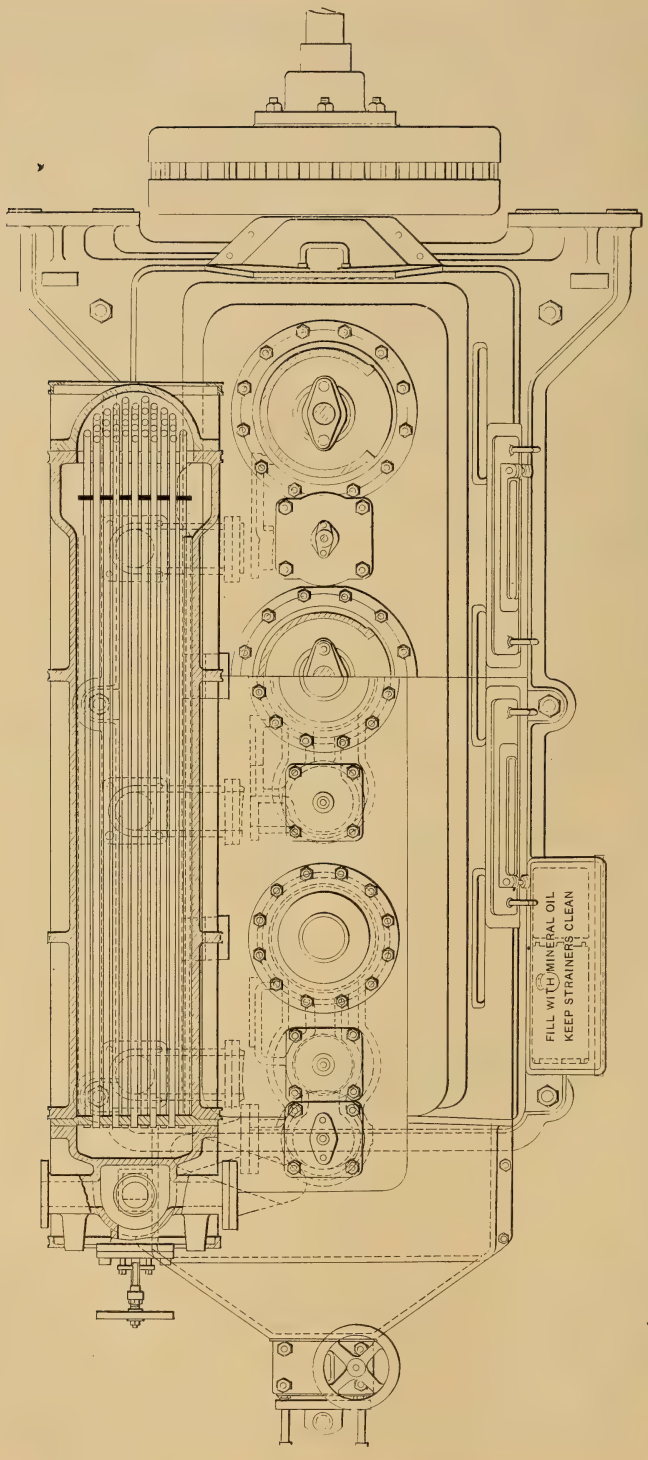


FIG. 6.—PLAN OF A THREE-CRANK ENGINE, WITH THE SCHMIDT SYSTEM OF SUPERHEATING, INSTALLED BY MESSRS. EASTON & CO., LTD., LONDON

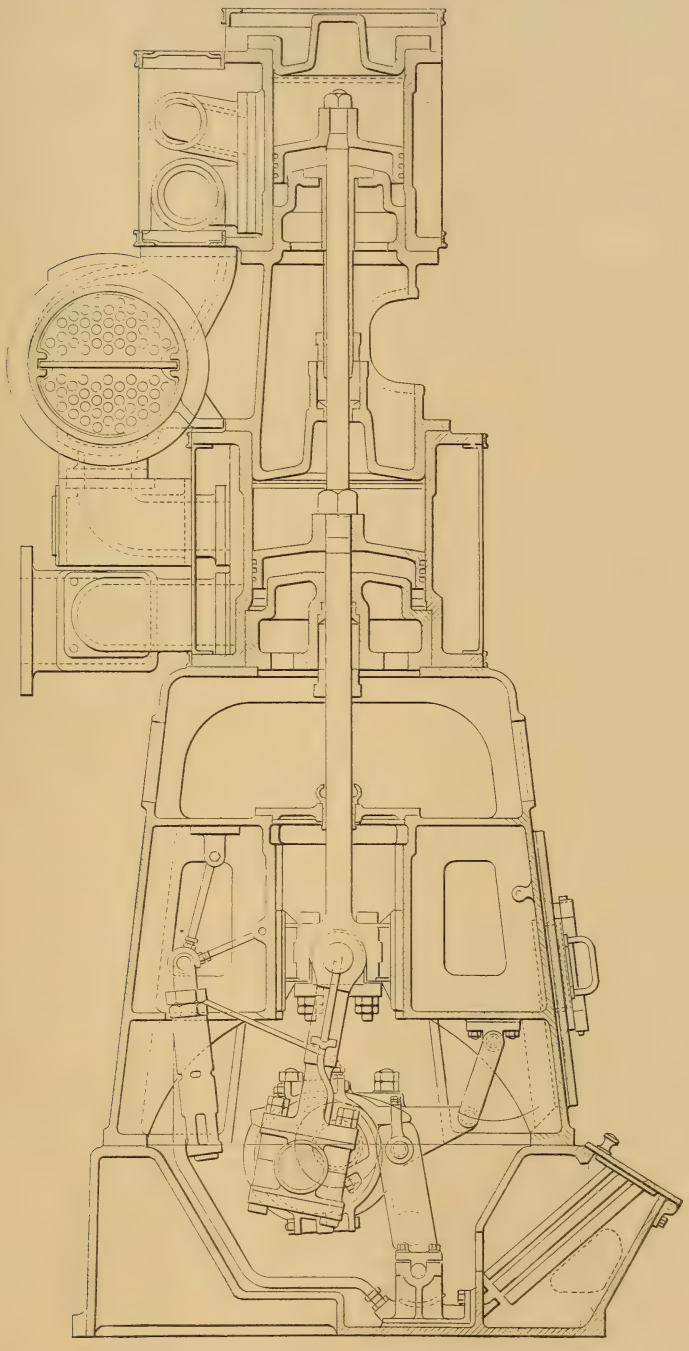
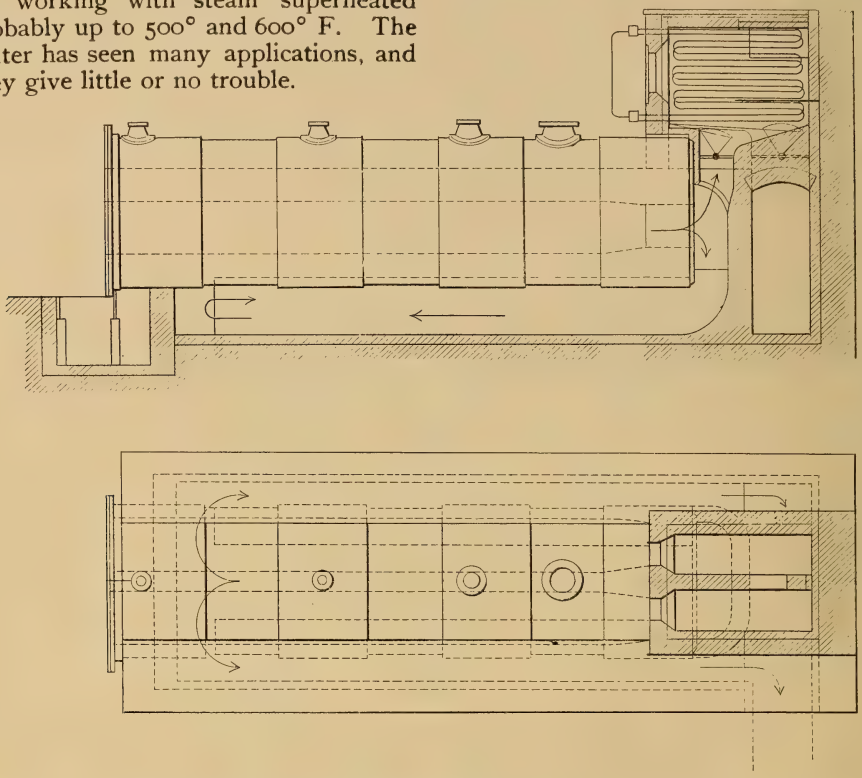


FIG 7.—VERTICAL SECTION OF THE ENGINE SHOWN IN PLAN ON THE OPPOSITE PAGE

number of Schwoerer superheaters are now in use on the European Continent, and some in Great Britain. From five hundred to one thousand steam engines are working with steam superheated probably up to 500° and 600° F. The writer has seen many applications, and they give little or no trouble.



FIGS 8 AND 9.—SECTIONAL ELEVATION AND PLAN, SHOWING A SCHMIDT FLUE-FIRED SUPERHEATER ARRANGED ABOVE A BOILER

Professor Ewing made two very careful tests in Holland several years ago on the same compound engine, first with superheated and next with saturated steam, and a few of the chief results may be given, as they are very remarkable. The engine was a horizontal, condensing non-jacketed engine, with cylinders side by side; it was made by a well known Dutch engineer, and fitted with the Schmidt system of superheating. The steam between the two cylinders was also considerably heated up by the Schmidt method as it passed from the high to the low-pressure cylinder. The engine is shown in Figs. 4 and 5.

The high-pressure cylinder has a piston valve, and the low-pressure a flat slide valve. The engine is not of the single-acting type generally adopted by Schmidt abroad, but double-acting. The stuffing box is of metal, of a special make, suitable for hot steam, and works well. In the receiver, or re-heater,

ber of superheating plants have been installed with satisfactory results. In the complete Schmidt system the steam is first superheated to a temperature of 700° F. or even 750° F., but it gives up a portion of this high superheat to the steam in the intermediate receiver, causing that steam to become moderately superheated, after it has lost its initial superheat through expansion in the high-pressure cylinder. Thus the high-pressure steam has its temperature reduced to about 550° F. or 600° F. before its admission to the valve chest. At such temperatures no difficulty is experienced in the working of the engine or in maintaining efficient lubrication. The hot gases after they leave the superheater pass through an economiser and heat the feed-water. This allows the gases to be discharged at an exceptionally low temperature. To this feature, and to the reheater, by which some of the superheat is transferred to the low-pressure steam with the effect that the steam is kept nearly dry throughout the whole course of its expansion, much of the remarkable economy of the system is due. In the United States the Schmidt system is being exploited by the Providence Engineering Works, of Providence, Rhode Island. Two of three installations recently completed by them comprise a 1500 h. p. and a 400 h. p. engine, using steam at 140 lbs. pressure, superheated to 650 degrees Fahr.—THE EDITOR.

placed between the two cylinders, an exchange of heat takes place between the superheated steam on one side of a nest of small tubes. and the exhaust steam from the high-pressure cylinder on the other. In this way superheated steam is supplied to both cylinders.

Figs. 6 and 7 show the system applied to a triple expansion, vertical, high-speed engine of the "Erith" type running at Messrs. Easton & Co.'s works.

The superheater and economiser tubes at the end of the boiler consist of nests of small tubes about 1¼ inches in diameter and have a heating surface of about 457 square feet. The gases of combustion escape from the boiler at the low temperature of 347° F. or much lower than is usually the case. The high-pressure cylinder is 16 inches in diameter, and the low-pressure 25½ inches, with a uniform stroke of 15¾ inches.

Two tests were made, as previously stated, one with superheated steam and the other with saturated steam of 140 pounds pressure. In the trial with superheated steam the amount of superheat was 385° F., namely, from 360° F. (the temperature of saturation) to 754° F., which was the temperature at which the steam left the superheater. But it gave up a portion of this superheat to the low-pressure steam in the reheater, with the result that the temperature of the superheated steam at the valve chest of the engine was 557° F. With superheated steam in the receiver, the temperature of the steam between the cylinders was raised from 232° F. to 361° F., or 161° F. of superheat. I.H.P. with superheated steam, 184¼; with saturated steam 124.8. Feed water per I.H.P. per hour, 10.4 pounds and 17.2 pounds respectively. Pounds coal used per hour per I.H.P. 1.3 pounds and 2.1 pound, respectively, or 37 per cent. less coal when using superheated steam.*

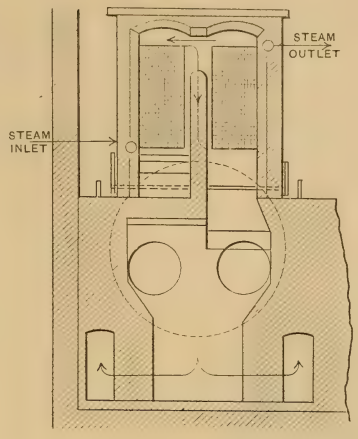


FIG. 10.—VERTICAL CROSS SECTION OF THE DESIGN IN FIGS. 8 AND 9

As an application to marine engineering, the experiments with the steamships *Inchdune* and *Inchmarlo* are interesting and instructive, showing very economical result. The temperature of the superheated steam used was about 500° F., and the coal consumption was 0.97 pound per I. H. P. hour. These results were obtained with a five-cylinder, quadruple type engine, all the cylinders being jacketed except the high-pressure. The steam pressure was about 250 pounds.

If due care and attention be paid to the points here noted, superheated steam has considerable economic advantages, and should certainly be more used.

*Later tests, made by Professor Ewing last December at the Brantham Works of the British Xylonite Company, near Manningtree, on an engine built by Messrs. Easton & Co., Ltd., of London, and fitted with a Schmidt superheater and a reheater between the high and low-pressure cylinders, gave the still better figure of 1.22 lbs. of coal per indicated horse-power per hour.—THE EDITOR.

In connection with the present article on "Superheated Steam," it may be interesting to refer to an earlier one on the same subject in this magazine for November, 1903, but dealing more particularly with the McPhail & Simpsons system of superheaters.—THE EDITOR.

PROBLEMS FOR THE ENGINEERING SCHOOL

THE NEED OF A MORE PRACTICAL EDUCATION

By James B. Stanwood

THE law of natural selection which, in the world of nature, by the process of the "survival of the fittest," seizes upon and fixes the best types from among an endless variety, and continues constantly to modify and adjust these types through variations in them to suit corresponding changes in condition or environment, also exerts its influence over that realm of human operations generally embraced by the term engineering.

This realm, relating chiefly to the industrial activities of man, as narrowly distinguished from the commercial and agricultural, although profoundly affecting them, is of modern origin, and has received its greatest impetus from the invention of the steam engine. Not that engineering operations did not exist prior to this valuable invention; on the contrary, for centuries roads, bridges, canals, and buildings had been constructed, manufacturing had been carried on in a small way, and the simpler forces of nature had been harnessed to serve man. But when the steam engine was discovered, a servant was found that would work almost anywhere, under all sorts of conditions, and at all times. With such a helper the scope of man's operations widened at one bound, and since its appearance his powers have continued to extend in expanding circles.

At first, those directly engaged in utilising the steam engine and its constantly increasing number of allies found themselves in a new field outside of all previous human experience. There were few guides or aids; indeed, no established laws or precedents; and as a result all necessarily were inventors, experimenters, discoverers, or investigators.

A great variety of applications of this agency, in the form of machines, mechanical movements, tools, processes, systems, and devices, have been brought out, and are still coming to light,—all to be tested in the school of experience. Out of this jumble, extending over a century in time, certain permanent types have been and are being evolved by natural selection, some already well recognised, others promising to become most useful in the various departments of human life. It cannot, however, be assumed for an instant that this field, thrown wide open by the invention of the steam engine, is in any way exhausted; indeed, its boundaries are even extending, and the opportunities for new inventions and discoveries appear to be limitless.

But now, after a century or more of experimental invention, and after a century's experience in using these inventions and discoveries, the engineer finds another phase to his calling; besides inventing, he has to take part in the fixing of types. He must assist in making permanent well-known utilities by cheapening their production, so that they can be more universally brought to the service of man. Often what are thought to be permanent types are entirely displaced by a new invention or discovery, and often also some old and apparently useless invention is made valuable by some new processes or ap-

pliances. But it appears that most types have a life; they are not usually supplanted at once, but are gradually improved or modified, and the period of their existence is sufficiently long to give them a degree of permanence.

We thus find in the modern engineering profession two, perhaps three, distinct fields for activity. There is the inventor or discoverer on the one side, and on the other there is the producer or manufacturer. Between them is the constructor, heretofore chiefly a resultant of the inventor's efforts; but now he is the product of both sets of men, and will continue to be so in the future.

In the individual who starts out to become an engineer there is usually a dominant tendency toward one of these three phases of the profession,—invention, construction, and production. The complete engineer should be experienced in all three. The young engineer, in most cases, leans strongly one way or the other, and his bias is the result of personal traits or experience and environment. As a rule, one who, by taste or experience, has a strong bias for invention, makes a poor manufacturer; another, with a bias for manufacturing, is less inclined to be an inventor, although his inventive faculties may be called into play at times. The constructing engineer should be both inventor and manufacturer. As types of men illustrating, roughly, these three characteristics, we have Watt, the inventor; De Lesseps, the constructor; and Carnegie, the manufacturer.

One of the chief functions of the engineer is to invent, construct, or manufacture some device, engineering work, or machine which will save time. These, in popular parlance, are termed labour-saving; but in reality they are not labour-saving, but time saving contrivances, so related to man that by their employment he has more time to do other things,—to labour elsewhere, and thereby secure a larger part of the earth's fruit as a result of his exertions.

The Panama Canal is to be a great time-saver; the modern fast railway train and swift ocean steamship save time; the rolling mill and sawmill, with their large output per man, save time; the new high-speed tool steel, the jig, and the template, all save time.

Thus a man engages a carpenter to work for him, who comes equipped with the best tools and the necessary skill to use them; he finishes the job, say, in a day, and goes on the next to work for some one else. Had a poor workman been employed, with poor or no tools, it would have required two, perhaps three, days to complete the work. The good workman, by means of tools and skill, gets more pay per day than the other, and the employer pays less for the work. So by means of tools and skill both employer and workman are benefited. A saving in time is really effected, for the good workman saves enough over the poor one to work for one other employer, and perhaps several others.

"Time is money," and to finish work quickly, provided it is properly done, and to get paid for it as soon as possible, saves time and consequently money, and also creates a demand for more labour. The modern spirit of hurry in this sense has a philosophical significance.

In this process of time-saving the manufacturing engineer plays an important rôle. As the cost of production of all articles is largely dependent upon the amount of labour required to produce them,—less such a portion as is due for taxes, insurance, a reasonable return for capital and that portion absorbed by rent and monopoly,—it follows that the cost can be almost indefinitely decreased by time-saving devices,—if one only knows how.

Therefore, the chief aim in the producing engineer's existence is to utilise and increase the number of time-saving appliances. He knows the value of standards, of duplication of parts, of economies in handling and specialising work. He always has in mind the reduction to the least common denominator of parts, of details, and of operations, in order to have as many things as possible of one kind to do, and not many things of different kinds. In the long run the consumer gets the benefit of all these exertions, but the consumer

also offers a bonus to those who push ahead in these utilities over those who stand still. The latter are eventually and inevitably forced to drop out. The difference between the advantages possessed by the utiliser of time-savers and those possessed by the less progressive operator constitute the profit of the former. In factories where time-savers are successfully employed, there is always an increasing demand for labour in order to maintain the growth of the institution; where plants are dying, the demand for labour decreases.

The manufacturing engineer, by concentration of effort upon the more economical production of some well-known article, process, or machine in general demand, is thus able to widen its use, and adds to the general welfare of man. As a prominent manufacturer once said, —"There is as much room for invention in scheming and planning to cheapen and improve well-known existing machines as in inventing new ones."

In discussing the superiority possessed by one of the two carpenters previously cited, two advantages possessed by the efficient workman were mentioned, namely, tools and skill. Skill is usually acquired either by experience or at school. Luckily for all, "experience is a good master, though an expensive one"; but, on the other hand, systematic training received at a school which is properly conducted usually gives more satisfactory results. For the engineer of to-day the school seems to be almost a necessity if he desires to become highly skilled in his profession. Yet we have among us some very able engineers who have not been so fortunate as to have been able to attend any of the great engineering institutions, and who, in spite of this disadvantage, have gained places in the front ranks of the profession. Grant that the engineering college is a necessity, it must be confessed there is still ample room for improvement in methods of instruction.

Consider these institutions in the light of the three phases of an engineer's activities,—invention, construction, and production. To what degree do they train for these special ends? Usually their graduates are well-equipped with scientific skill, mathematical knowledge, and sufficient experimental data, so that, with these as tools, they are able later on to invent, construct, and to produce. But do these schools stimulate the inventive faculty, foster the constructive talent, or encourage the manufacturing instinct directly? On the contrary, these creative faculties usually lie dormant during periods of college life, while the analytic faculties are extensively awakened and encouraged. The deductive habit is developed and the inductive is neglected, while there should rather be a proper balance of both.

One difficulty lies in the character of the experience possessed by the instructive force. Most of its members have never had engineering experience. While practicing physicians are closely in touch with the work of medical schools, the practicing engineer is rarely in evidence in engineering schools, and the instructors usually have no practical knowledge; as a rule, they are excellent mathematicians and experimentalists, but few possess wide experience in the average life duties of the active engineer.

A reason for this state of affairs in the engineering schools and colleges is the practice of "in-breeding." The young teachers are usually recruited from among the graduates; their experience is limited to their school experience. This method of selection is pursued on account of financial conditions, because such young men can be secured at moderate salaries for positions as instructors and assistants, afterwards to develop into full-fledged professors; but the disadvantages of such a system are many.

Perhaps some day some one of great wealth will set aside a fund sufficient to secure the occasional services of an advisory group of prominent engineers, to be selected, say, by the presidents and councils of the different engineering societies, so that this group of men shall in some way, by advice or supervision, secure for some fortunate institution the benefits which the medical school secures

for its students by contact with live men of its profession.

Another difficulty lies in the methods of instruction as they often exist. Is there not even now too much of the recitation and lecture and not enough of the laboratory method? The latter is, undoubtedly, more used than formerly; yet, as carried out in some schools, the time spent is lost. Students have too much routine, they are made to mark time and to work in unison rather than being awakened to the true ideas of scientific discovery, investigation, analysis, and classification.

Then, too, to what extent has this method been carried on outside of the laboratory? Teaching mathematics has not yet fully succumbed to this treatment. It is usually a formal subject, taught abstractly by recitation, with a minimum of the concrete. It is, indeed, refreshing to find such men as Prof. John Perry vitalising this old, dreary, theoretical desert by means of the laboratory system. It is to be hoped that his or some similar method will make this subject a real mental tool for the engineer for wresting practical results from nature instead of its being a logical, abstract system rarely used in active engineering life. As a study, abstract mathematics may give better mental training than Latin or Greek; but an engineering student has so much to learn that methods which will produce results more directly are of themselves valuable as time-savers.

In order to broaden the efficiency of technical schools the art of teaching should receive more attention than it now does by the average instructor or professor. Although the art of teaching is in many cases a gift, yet the most talented professors should strive to perfect themselves in it by acquiring an exhaustive knowledge of the principles underlying it. Teaching requires a knowledge of psychological processes, and teachers, gifted or otherwise, can improve their work by recognising and using the experience gained by man in this branch of science. A course in pedagogy would benefit many a young professor by curbing or exciting his conduct of the laboratory, recitation, or lecture room exercises; he must not only teach his subject, but it is his duty to produce thinking men as well, and not to produce what a recent writer calls "cold storage houses of facts and information."

In conclusion, while recognising the calls that are made upon technical schools for various courses of study, it has often been wondered at why the subject of the economical handling of material has not attracted the attention of professors. Problems of this nature arise continually for engineers to solve, for example, those involving the use of the elevator and conveyor with their application to handling grain, coal, ore, lumber, iron, steel, etc.; or the pipe line as applied to handling liquids and gases, such as water, steam and gas; or the excavator and dredge, the travelling and swinging crane, and various loading and unloading devices; also the various systems of haulage and lifting, either rope, electric, or pneumatic power. A course of work of secondary importance embracing modern practice along these lines would be of great benefit to all engineering students, who usually have to work out such problems later with few or no data.

As contributing to the experience of the producing engineer, students might be given some elementary ideas as to the methods of cost-keeping; or the relative value of material, labour, and expense; also the reduction of cost as effected by time-savers.

Their mental capacity might be improved by offering them more of the live problems of the profession, and curtailing, by more efficient treatment, the theoretical branches, especially when these tend to run into pure speculation.

The technical graduate should be embued with the idea that there is work to be done, and that he has been in training so that he can intelligently do his share; and he should realise that he is not a master, but a workman in the ranks, who has had the rare good fortune to be well equipped with mental tools and to possess a slight amount of skill in the use of them.

ARCTIC RAILWAY BUILDING

By George E. Walsh

TRACK LAYING ON THE COUNCIL CITY & SOLOMON RIVER RAILROAD

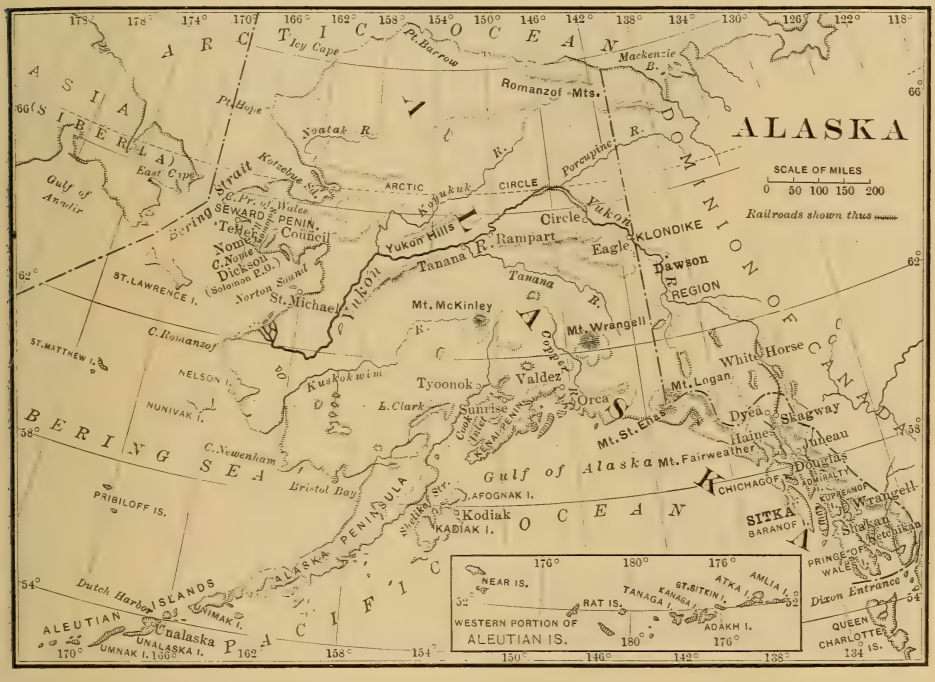
THE development of Alaska has advanced considerably within the past few years, and whether or not the gold supply continues to yield fabulous wealth for those lucky enough to locate untouched veins, the country will undoubtedly furnish an abundance of crops to stimulate the growth and settlement of a large population. The keynote to the whole situation has been in the past, as it is to-day,—transportation. Facilities for carrying the products of the mines and the fields from the inland districts to the coast have always been of the most primitive nature. Obstacles of an unusual nature have also impeded the development of transportation engineering to such an extent that it seemed doubtful for many years if such a cold, barren country could ever be made of much value.

Russia sold the great northern peninsula to the United States partly because of lack of faith in its future, and the price paid for it was small indeed in comparison to its present day value. Russia has her own problem of opening up her Asiatic provinces, and Alaska was, in effect, of little real value to her, as it could not, for many decades, have returned anything on investments made. In Siberia the transportation problem is on a par with that which Alaska faced ten years ago. Beasts of burden were depended upon to carry the mail and freight from one part of the country to

another, and the huskies and reindeer reared for this purpose apparently answered the needs of the day.

According to some experts of a dozen years ago, the only apparent hope of making anything of Alaska was to import and breed reindeer, and train the natives to use them as beasts of burden over the snow and ice during the long winters. Several thousand of these reindeer were brought from Lapland by United States Government agents, and these have so multiplied in their new usefulness, gave clothing and food to the owners. It is prophecied that 10,000,000 reindeer will eventually live in Alaska, and this number can thrive on the tundra moss which can be found in the valleys during the coldest winter.

The government has established several long reindeer mail routes, and the service is maintained regularly over the snow to the most northern point yet reached in a regular way. This route runs over a thousand miles of desolate snow drifts, mountain passes, and



home that to-day there are in Alaska over 10,000 beasts of burden, besides the pack dogs engaged in the transportation business.

According to the latest United States Government reports of the reindeer stations and breeding farms, the imported animals were easily domesticated, and they not only thrived in the land, but proved valuable animals to the natives in many other ways. Their milk furnished excellent food for the sick and weak, and their hides and bodies, when the animals had passed their period of stretches of low frozen meadows. In the winter season the mail carrier and his pack are frequently delayed for weeks in the blizzards, but the hardy nature of the reindeer enables him to finally reach his destination even in the face of such difficulties.

But the reindeer and dog trains are, after all, representative of only a crude form of civilisation, and the country could never reach a high point of development if dependent entirely upon them. The modern steam road or electric trolley must be introduced to ad-

WITH THE STEEL GANG ON THE COUNCIL CITY & SOLOMON RIVER RAILROAD

vance the country in its commercial and industrial life.

Railway building in Alaska under the Arctic Circle practically began when the discovery of gold in the Klondike region startled the world, and a few pioneer railway men undertook to construct the White Pass & Yukon Railroad. This line was the pioneer in the great northern country. Its construction was an engineering feat of no small importance, for, considering its length of only 112 miles, it probably had more engineering difficulties to overcome than any other railway in the world.

Since its construction the operation of this short road in winter is a matter of great difficulty, owing to the severe storms which sweep down the mountains and fill the passes with snow and ice. The winter season is a long one, too, in the far north, and its duration must determine, to some extent, the value of a railway operating in the country. Weeks at a time the northern roads must be closed down, literally buried under great banks of snow and ice. The question whether a railway could be operated in the northern part of Alaska under such conditions was repeatedly raised, and those who ventured to construct the Yukon Pass road were considered unwise in their investments. Yet events have demonstrated the value of the road, both to the public and to the owners.

Last year this same road paid 60 per cent. dividends to its stockholders, and its stock sold in Chicago at the exceedingly high price of $750 per share. When the shares were first offered to the public they were sold at $6.50 apiece, and the par value was $10. This phenomenal increase in value is due to the rapidly improving conditions in Alaska, and to the tremendous impetus to travel given by the line. Summer visitors now go through the Yukon

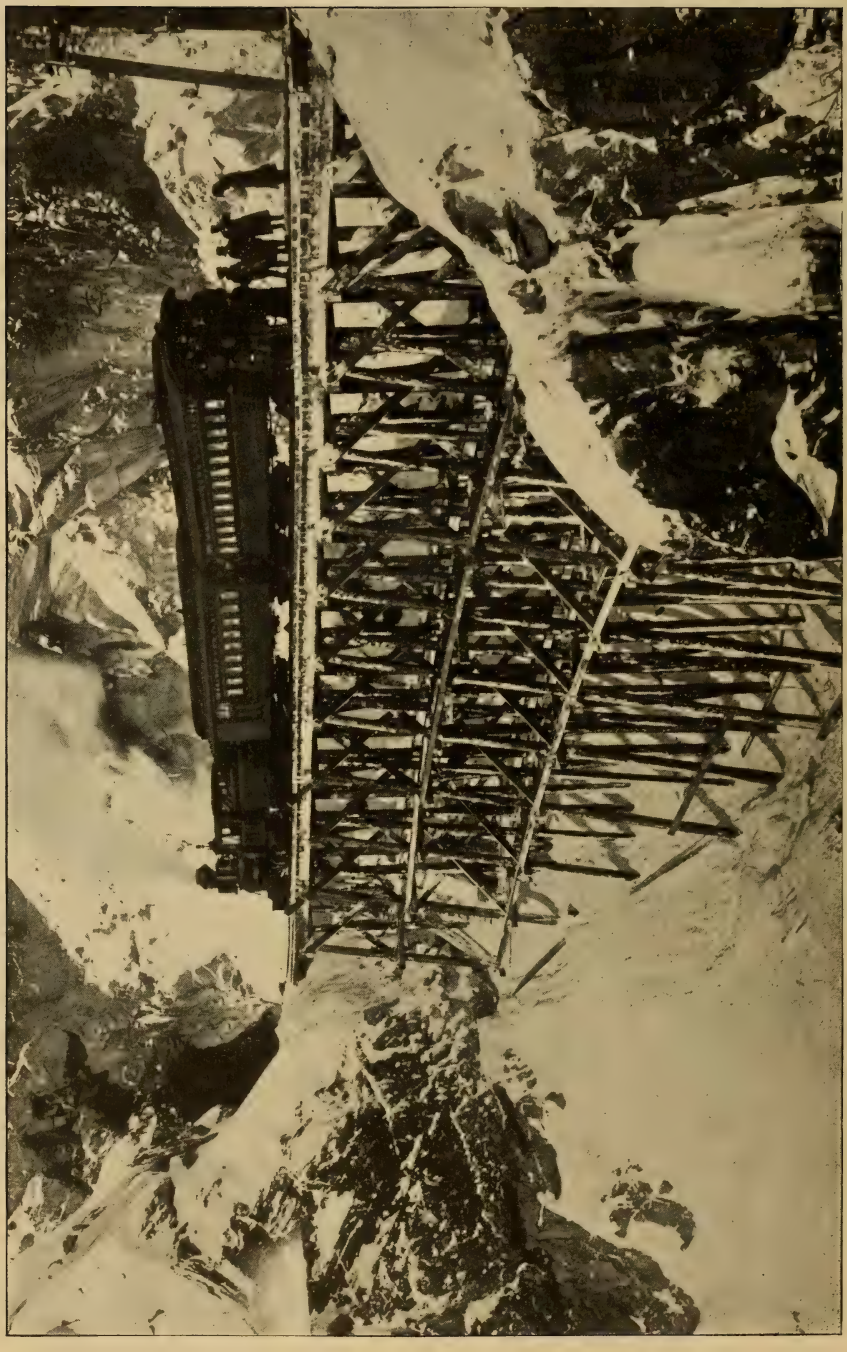
Pass in ever increasing numbers, and all along the old trail covered by the road adventurous tourists swarm in summer.

As a matter of fact, this pioneer northern road has proved as advantageous to the public as to its stockholders. Besides annually attracting thousands of tourists to the old gold fields, the road has benefited the dwellers within the Arctic Circle by greatly reducing the cost of living. Before the line was constructed it was very costly to get supplies in the gold region, as they had to be taken over the pass on the backs of men. This cost from 30 cents to $1 per pound, and the goods delivered in Dawson at this price were well worth it. In the rush season of the year it was impossible to hire enough men to carry the goods over the pass for the outside price.

The building of the railway, however, immediately altered conditions. Besides opening an artery of travel which could accommodate all who wished to pass on to Dawson, the road brought the cost of goods transportation down to something less than five and six cents per pound. To-day the official charge averages four and three-quarters of a cent per pound. The benefits to the gold seekers and settlers in the Klondike region, and Dawson in particular, are naturally great; but the chief good comes from the continued rush of new settlers to the region, who are attracted both by the gold prospects and the fact that Alaska offers a fertile field for other industries.

The development of Alaska is sure to come. The increase in the population in the past five years has been some-

THE FIRST PASSENGER TRAIN TO LEAVE LAKE BENNETT ON THE WHITE PASS & YUKON RAILWAY, CARRYING NEARLY A MILLION DOLLARS IN GOLD DUST



THE FIRST PASSENGER TRAIN OVER THE WHITE PASS & YUKON ROUTE TO THE SUMMIT

thing like 500 per cent. But gold mining alone will not be the great industry of this land. The fertile valleys and coast lands afford an abundant opportunity for a farming population to thrive, and, according to the special investigations of the United States Department of Agriculture, rye, oats, and various grasses can be made to flourish so abundantly that the cattle industry may become important in the near future.

In parts of Alaska there is absolutely no timber, but in other sections it is extremely abundant. It would require centuries for the native population and new settlers to exhaust the present lumber supply; but its unequal distribution

CONSTRUCTION TRAIN WITH MEN ON THE LINE OF THE COUNCIL CITY & SOLOMON RIVER RAILROAD

is a disagreeable feature of the country's resources. For instance, on the Seward peninsula,—which promises to become one of the most important sections of Alaska, and where new railroad enterprises are now in the course of development,—there is no timber within thirty miles of the coast. The same is true of the gold mining regions. At Nome and Solomon City lumber is an expensive commodity, costing from $200 to $300 per thousand feet. Most of the lumber used there and on the coast is brought from Tacoma and Seattle. The timberland consequently would be extremely valuable if proper transportation facilities were provided.

For developing these resources railways are absolutely imperative. The construction of the White Pass & Yukon Railway proved this by opening up the Klondike region to the civilised world. Cape Nome is fully as important as the Klondike region, from the gold seeker's point of view; but it has a barren coast so rough and inhospitable that ships cannot approach nearer than two or three miles. There are no good harbours, and the ships carrying supplies to this place have to lighter their cargoes ashore through a difficult sea. It is not only a wasteful practice of getting supplies into Cape Nome, but it is dangerous and expensive. With even such poor facilities for landing cargoes, and the resulting high prices for all the ordinary commodities of life, the city of Nome has sprung up and grown into a town of 20,000 inhabitants. The excuse for its existence may be the hidden treasures of gold, but it is a city established to stay. Its inhabitants are branching out more and more into new lines of industry. Farming, timber-raising, hunting, and even manufacturing are developing about this city of the far north.

Two years ago the traffic from the coast to the city became so great that a second railway was built. This small road was known from the beginning as the "Wild Goose Railroad." It connects the city of Nome with Anvil Creek, and, although only about five miles long, it has proved an excellent feeder

MAIN STREET IN NOME

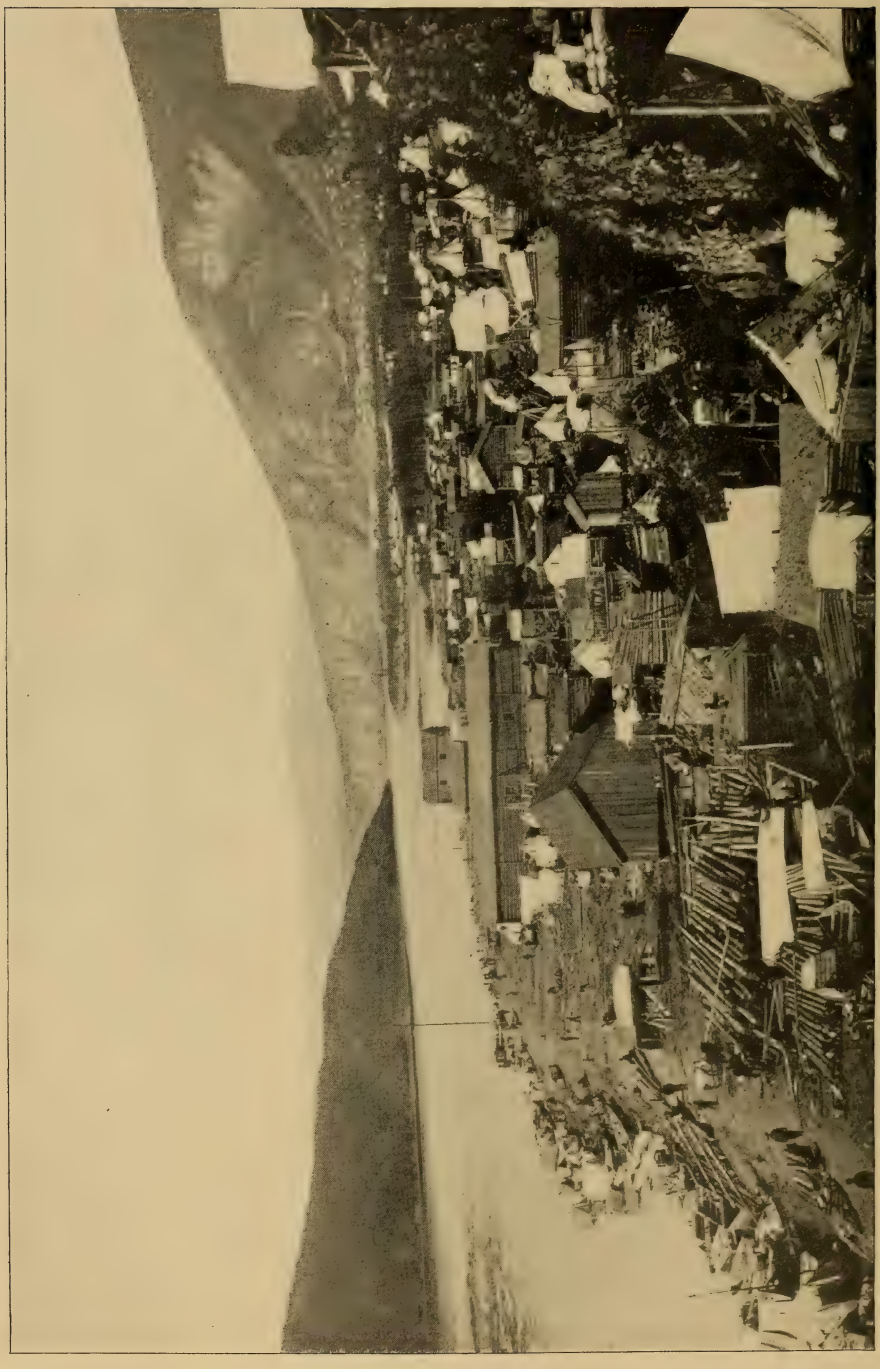
to the city. Miners and tourists coming from Anvil Creek and the coast can take the railway and cross the five miles of rugged country in comparative ease and comfort.

This little "Wild Goose Road" has proved a money-maker, for it has in a single summer made more than nine times the cost of constructing and equipping it, and its stock has soared far above par. The cost of this road was not great, and its equipment is somewhat primitive; but in the land of eternal snows and ice it is a glorious little time and labour-saver. It compares favourably with the three million-dollar White Pass & Yukon road connecting Dawson City with the coast of Skagway.

ARRIVAL OF THE FIRST PASSENGER TRAIN AT THE SUMMIT OF WHITE PASS ON THE WHITE PASS & YUKON ROUTE

Railroad building has thus been started most favourably, and the activity of new companies organised to build more lines under the Arctic Circle is quite apparent. The "North Star Line" is now in the course of construction, and in some respects this new road will eclipse anything yet attempted in Alaska. It will open up one of the most important and valuable sections of the country, and provide the key to the great Trans-Siberian-Bering Strait Railway route which is now under serious consideration by a group of eminent capitalists. The dream of an all-land route to Europe by a tunnel under Bering Strait is no longer a picture of the imagination, but promises to become an assured fact within the present decade. There will be fewer engineering difficulties and expenses in building it than in cutting a canal through Panama. Surveys of the route have already been made and studied, and capital has actually been organised to undertake the preliminary work.

The new road, or "North Star Line," will become an important feeder to this new overland route, or possibly a part of the main branch. For the present, however, it opens up a part of the Seward Peninsula. This small peninsula juts far out into the ocean, and almost reaches Siberia. It contains famous Cape Nome, and it is rich in gold deposits and fine agricultural land. The



A VIEW OF KLONDIKE CITY

ENGINE NO. 1 ON THE COUNCIL CITY & SOLOMON RIVER RAILROAD,—THE FIRST ENGINE ON THE FIRST STANDARD-GAUGE RAILROAD IN ALASKA. THIS LOCOMOTIVE IS ONE OF THE NEW YORK ELEVATED RAILWAY ENGINES WHICH WERE DISPLACED BY THE PRESENT ELECTRIC SYSTEM THERE, AND OF WHICH A NUMBER ARE NOW IN ALASKAN RAILWAY SERVICE

Solomon River runs up through a part of this section, affording a fine harbour on the coast thirty or forty miles east of the city of Nome. This is about the only good harbour on the southern shore of Seward Peninsula, and its importance is easily recognised. Solomon City, at the mouth of the river, has grown rapidly, and is now an important sea port.

Fifty odd miles from the river's mouth is Council City, another town which has had extremely rapid growth. The North Star Line will run from Solomon City to Council City, and thus connect the sea coast with a distributing point far up in the interior. The whole interior of the Cape Nome region will thus be opened up and a new impetus be given to traffic both in freight and passengers.

The building of this railway is far less of an experiment than either that of the White Pass & Yukon line or the Wild Goose road, as others soon to be projected will prove easier and less experimental than the North Star Line. The road will be constructed on comparatively level land, following the course of the river's bank, and cutting through very few high hills. When finished it will tap one of the richest timber regions of Alaska, making it possible to construct it at less expense than most of the other roads, which have had to use timber ties brought from Oregon and Washington. The growth of timber in the region of the new road is very dense and valuable, and its distribution to the coast cities will prove of great commercial importance.

The whole Seward Peninsula has been mapped out with railway projects, which in a short time will undoubtedly be completed. It will also produce large crops of barley, oats, and buckwheat, to support an extensive cattle-raising industry.

There are few countries better fitted for cattle ranges than the coast of this peninsula, as the Japan current warms the coast to a moderate temperature, even though the interior may be locked in ice and snow.

Carrying freight from ships inland from forty to fifty miles costs about $200 per ton to-day; but with the new railways constructed, the same freight will be carried for less than one-tenth of that amount. Railway prospects in Alaska are thus more promising than in any other part of the United States. The Western Alaska Construction Company, engaged in building the new North Star Line, will spend upward of a million dollars in the next year in opening up the Solomon River region, while the other companies organised will expend several times this amount.

Overland to Europe, by rail to Alaska, and under the Bering Strait by tunnel, will complete one of the present-century engineering plans, and, with this accomplished, the seven odd million dollars paid to Russia for the whole peninsula will prove a mere bagatelle to the actual commercial benefits that the United States will derive from that country.

Current Topics

EVERY now and then there appear on the market compounds of various names, from the application of which to coal great benefits are promised in the way of economy. These compounds are usually in the form of a powder, soluble in water, for which it is claimed that the use of a few pounds per ton is sufficient to accomplish the desired results. The fact that the business connected with the introduction of these nostrums, as they may be called, is usually short-lived, is sufficient evidence that they are practically worthless, and, this being so, it is only through some species of deception that the question of their introduction in connection with a plant of boilers is likely to be entertained. As an instance of this sort reference may be made to a recently published comparison between coal untreated by one of these compounds and coal of an inferior character which had been so treated. One boiler used coal costing nearly $5 per ton, and another in the same plant used a mixture of screenings and cinders which cost a little over a dollar per ton. The use of the compound on the low-grade coal, it is claimed, reduced the cost of fuel to about one-third. By analysing the figures that were given, it appeared that

while only three tons of the inferior coal were used in one boiler and four tons of high-grade coal in the other, the one using the cheaper fuel produced a smaller amount of steam than the other, and, consequently, the comparison unduly favoured the fuel on which the compound had been used. It is quite probable, too, that the boiler using the cheaper fuel could have obtained the same results, or substantially the same results, without the use of the compound, and the net result would have been better without the compound to the extent of the cost of this material. Evaporative tests have been made with and without such compounds, using the same boiler and the same fuel, and it is generally found that the advantage of using the compound, if there is any advantage at all, is so small as to be hardly worth considering.

One of the problems to which engineering schools ought to give immediate and serious consideration has grown out of the practice of obtaining professors by "in-breeding," as Mr. J. B. Stanwood characterises it in an article printed elsewhere in this issue, meaning by this the recruiting of the young teachers, soon to be developed into full-fledged professors, from among recent graduates, with little more than their school experience to their credit. This species of selection has become an increasing fashion within the past ten years, or perhaps better put, an increasing necessity, due to the cramped financial conditions ruling with most of the schools, and the result has undoubtedly been a narrowed degree of usefulness of instructors and professors, and a more closely circumscribed value in the engineering market of the young graduates forced into it. In a few instances, it is true, prominent engineers, actively engaged in professional work, have been induced to lecture occasionally at such schools, thus vitalising the college atmosphere with the spirit of actual engineering, and through such lectures some good has been accomplished. In several recent instances, also, men fresh from engineering fields have been secured as the heads of engineering school departments, and as such afford admirable illustrations of a policy which is to be much commended. But these are only isolated examples of what should be general practice.

It is obvious that wireless telegraphy is applicable to almost any of the commercial uses to which wire telegraphy has been put, within certain limits, as, for instance, the distance to which signals may be successfully transmitted by the wireless system. This being true, it is, therefore, self-evident that it should be quite feasible to make use of the latter system in exactly the same way that wire telegraphy is used. Hence, if Mr. Paul Jones runs short of ready cash while on a transatlantic trip and knows that Père Jones is on a sister ship, it is not a miracle to send a message by wireless, if both vessels are equipped with wireless outfits, in order to obtain an order for more of the needful from Père Jones to Jones Fils. Yet the prominence given in the daily press to so simple a transaction would imply that there was something of the supernatural about it. It is also quite apparent that if wireless telegraphy is practically operative at all, it should be feasible to apply it as a means of communicating to and from moving trains. Hence we hear of various inventors who are assiduously applying themselves to accomplish this result, seemingly without asking whether, if their efforts should be successful, there would be any demand for such a system of inter-communication. It is not novel to accomplish such a result. It was done long ago by Phelps, Edison and others by induction telegraph methods in a very simple and successful manner, but there was no demand for it; and it is, therefore, not likely that a system not nearly so simple, economical, or, it may be assumed, reliable, will create such a demand. Another somewhat unnecessary proposed employment of wireless telegraphy has recently been proposed and tested, namely, for auto-

matic fire alarm telegraph purposes. For this work nothing could well be more simple, reliable and practical than the ordinary wire circuit connecting the building to be protected with firemen's headquarters. Such an alarm system, to be of any practical utility, must give automatic evidence of some kind when defects of any sort arise; or it must be feasible to test the circuits and apparatus at regular intervals. All this is readily done from headquarters by the existing wire telegraph systems, with little or no complications at the protected building. With wireless telegraph apparatus, however, a complete transmitting and receiving system would be necessary at each protected building to effect the results just mentioned, the cost of which would, doubtless, be many times more than the cost of a connecting wire. Besides, who is to keep the coherer, induction coil, battery, and other accessories in adjustment night and day in the various stations? The moral of which remarks is, why waste time, energy and money in demonstrating that certain things can be done by wireless telegraphy when they can be, and are, done much more satisfactorily by other means?

THE warship whose engines give out, is doomed to almost certain destruction in the next naval battle, for she will be a target that no torpedo will miss even at several thousand yards' range. Breakdown ought, therefore, to be made as nearly impossible as human foresight will allow. This substantially is the text of a vigorous discussion of that already much-discussed subject, the weight of warship engines, in a recent issue of the London *Engineer*. There are several ships in the British service now which, we are told, have passed their trials satisfactorily, but have been a source of worry ever since. That worry is entirely due to the uncertainty as to what will go when the engines are working for any length of time at full power. Too often something does go. Usually it is a minor mishap, and not much is heard about it; but the minor mishap may be the most deadly of any in war time. As a scientific problem the construction of machinery just able to stand what will be required of it is very pretty; but as a practical entity the charm of it soon wears thin. Even supposing that things stand that uncertain extra strain which the sea may produce, a burden of unnecessary worry is placed on the chief engineer. He is given sleepless nights over a saving of weight not perhaps greatly in excess of his own, and this strain, though it may be borne with in peace, will be a serious factor in war. In a word, the price paid for the economy is greater than the advantage secured. To the ship the advantage of saving a few tons is trifling. She is of, say, 14,000 tons, and cheese-paring in the machinery allows so much more weight for armour. But this will not work out to more than an extra inch or so in the height of the belt, or perhaps a foot or so added to its total length.

No doubt the gain is something, but both objects could have been secured on, say, 14,100 tons displacement. It would not have mattered had the displacement risen even to 14,500, except to those critical gentlemen who write of comparisons of what ships of different nations give per ton. The more guns and armour a ship shows for her displacement the better they are pleased. High speed and a good coal capacity also pleases them. Beyond that they rarely, if ever, go. The less the displacement of the ship for a given armament, armour, speed, and coal supply, the better the design with the popular critic. The steady expression of popular opinion under these heads, as any steady expression of public opinion must, has made itself felt officially, and the policy of saving weights has grown accordingly. Extravagance in weights is to be condemned; but extravagant economy is to be condemned still more. Allowance, of course, can be made for progress; but when machinery weights decrease in inverse ratio to increased power, we may well pause to inquire

how much is due to progress and how much to a desire to tickle popular fancy. Certainly, naval engineers are one in thinking that the last ounce in the engine room was saved long ago; and there are probably few firms who construct warship machinery who would not welcome very gladly the opportunity to do a little less cheese paring in the future. In the day of battle, warship machinery will have to stand the as yet unknown extra strain of projectiles hitting the belt. It would appear that a great deal more than a bare margin of strength of parts will be demanded here; indeed, there are many who believe that this particular eventuality should necessitate every effort to make the machinery as strong as possible. The policy followed, however, is the exact reverse of this.

Some measure of the reduction of weight of propelling machinery in warships effected during the past forty odd years is afforded by figures given in Sir William H. White's recent presidential address before the Institution of Civil Engineers. According to these, each ton weight of propelling apparatus, in full working order, gave about 6 indicated horse-power in the year 1859, whereas in present practice about 9 indicated horse-power are obtained in battleships with cylindrical boilers, and about 10½ horse-power with water-tube boilers. In large cruisers with water-tube boilers about 12 horse-power per ton are obtained; in third-class cruisers with water-tube boilers, having thinner and smaller tubes, about 20 horse-power; and in destroyers from 40 to 50 horse-power. The large cruisers have proved themselves capable of developing about 75 per cent. of their maximum power for continuous steaming at sea, which corresponds to 9 horse-power per ton; for the small cruisers and destroyers 50 to 60 per cent. of the maximum power can be maintained as long as the coal lasts; taking 50 per cent., this gives 10 horse-power per ton weight for the cruisers, and over 20 horse-power per ton for the destroyers. In mercantile practice the policy of weight reduction has not been carried so far, and larger margins of weight in proportion to power have there been allowed. Still, there, too, there have been savings. In 1859, for example, the best direct-acting screw engines developed on service 3 to 4 horse-power per ton. Now the corresponding development is 6 to 6.5 horse power per ton in swift mail steamers of the highest class, in ordinary cargo steamers 4 to 5 horse-power, and in cross-channel steamers making short passages with high-forced draught in the boiler rooms, cylindrical boilers, and quick-running engines of short stroke, it rises to 10 horse-power per ton. The last-mentioned conditions would not, of course, be applicable to long sea voyages.

To the particulars given in the preceding paragraph it may be interesting to add, on the same authority, that in 1859 the highest steam pressure used in marine boilers were from 20 pounds to 25 pounds per square inch; twenty years later 90 pounds to 100 pounds had been reached, and the compound type of engine was in general use. Now, in the mercantile marine, with the ordinary (water-tank cylindrical) boilers, pressures of 210 pounds to 220 pounds are common, and a little less than 270 pounds has been reached in a few cases. For warships, with water-tube boilers, pressures of 250 pounds to 300 pounds have been used for nine years; but in the most recent vessels, in which 20 per cent. of the total power is in cylindrical boilers, with the balance in water-tube boilers, the pressure adopted is only 210 pounds. With these high pressures triple or quadruple-expansion engines are associated. This rise in pressure and greater expansion have been accompanied by an increased rate of revolution and piston speed. In 1859 for the best types of engines in screw steamers the revolutions did not exceed 50, and the maximum piston speeds were about 400 feet per minute. In 1881 the averages for merchant steamers were about 60

revolutions, with 470 feet per minute piston speed; now, the corresponding averages are nearly 90 revolutions and over 650 feet, while many steamers of high speed attain piston speeds of 900 feet to 1000 feet. For swift cruisers of large power, 120 to 140 revolutions and 1000 feet of piston speed are now common; smaller cruisers have about 220 revolutions with equal piston speed; and destroyers have 350 to 400 revolutions and 1100 feet to 1200 feet piston speeds.

SYSTEMS of shop cost keeping have been so much harped upon, both in papers before technical societies and in technical periodicals, that it would seem as though pretty nearly everything had been said and printed about them that could be thought of, and in very many instances the only result has been a waste of time and printer's ink. When a system of any kind requires several additional systems and a special staff to keep it going properly, it is safe to conclude that it is not what you want. It is not likely, in that event, to be a time and money-saver, and that is what the right kind of system should be. W. Osborne, in one of his entertaining letters to *The American Machinist*, recently put the matter to his readers as follows:—"A man has a wonderful scheme for keeping track of work. By it every move of every man, and every operation on every piece, is known at any and all times. Of course, this system is not self-working; someone has to see to it. A man can make a limited number of marks with a pen or a pencil in a day. He can handle a number of cards or pages of books in a day. To make a large number of marks or to handle a large number of cards might take more than one man. These men would have to be paid money. Is the money that would be saved by knowing these things more than the additional cost of getting the knowledge? Here is a conundrum which all may not answer alike:—Would you rather have $2 and not know just how you made it, or be short $2 and know all about it? A superintendent of a large machine works managed to find room for himself and a friend in a small room that I have tried to dignify by calling it an office. The shop wasn't big enough to need much of an office anyhow. After we had chatted together for a few minutes he remarked, 'By the way, Osborne, have you been keeping yourself posted on the latest improved systems of cost keeping?' I replied that I had been giving a little attention to it, and showed him a book that was well spoken of as being one of the latest and most complete expositions of the subject. 'Yes, I have a copy, and I was up to Blank's to see how his system worked. His system was put in by an expert who did a lot of the writing for that book. Blank can tell by the way that the cards change colour just how a job is coming along. He can tell just where it is in the shop, and who is working on it, and when it will be ready to ship, and as soon as it is done he can tell exactly what it cost and whether he made or lost on it, and how much. He has the most complete system that I ever saw worked. Yes, sirree, it is a fine system.'

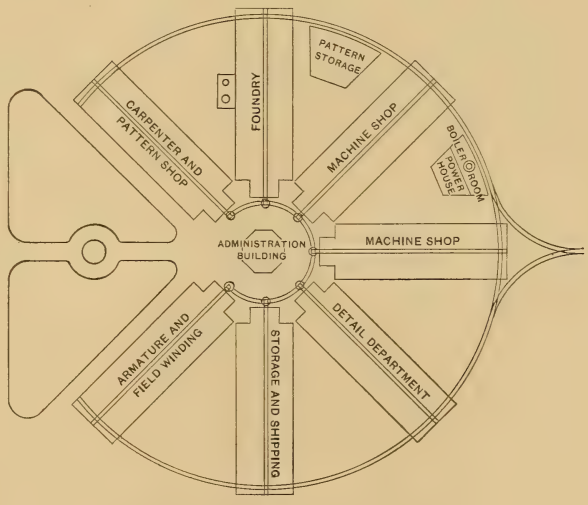
"'I suppose that you and I will have to fall in line and get it in, too,' said I, 'if it is so good.'

"'Well, I never was much on fine-haired book work, and you will have to make at least one change before you can put it in in this place,' said he. 'I have made a good many changes, good, bad and indifferent, in this shop in my day, and I guess I can stand it to make one more. What is it that I will need to do?' I enquired.

"'If you will move the shop in here you will then have room out there for the clerks that you will find work for on the system, and as you wouldn't have much work with that arrangement, you would have lots of time to see the beauties of the system. As a system, I tell you that it is the finest system that I ever ran across. If I wanted a system that was strictly up to date, and could afford it, this one would be *the* one,' he answered. 'But you see we are poor,

and are trying to make a little money, and can't afford many of the luxuries of the business yet. But it is a nice thing to show to people and to talk about.' ''

THE diagram below illustrates a distinctly novel form of shop construction proposed by Mr. F. A. Scheffler in a paper read at the recent annual meeting of the American Society of Mechanical Engineers. The plan, as shown, was primarily designed for manufacturing electrical apparatus, such as generators, motors, switches, and the like; but, of course, the same scheme would be applicable to any other kind of manufacturing where it is desired to have a number of shops, all of which are easily accessible, both for business purposes and for delivery and shipping of material. In the centre of the space available for the buildings is located an administration building, constituting the business, accounting, and sales offices; and on the second story, the draughting room. This building is octagonal, or hexagonal, whichever may be found to be most suitable for the purpose. In this case, it has been designed with a view of accommodating seven buildings, which radiate from each side of the octagon, and has one side reserved for the main entrance through the building. The end of each shop which is nearest to the administration building has its individual office for the foremen and shop clerks. This, it will be seen, is a very harmonious arrangement, as every shop is then but a short distance from the administration building, so that intercourse can easily be had between the drawing room, the main offices, and the offices of each shop. The general arrangement gives each shop plenty of yard room, which is also very essential; and travelling cranes, either worked by hand or power, could be located in the yard room between any two of the shops, for handling raw or finished material. A circular track around the administration building, connected in front of each shop building by means of suitable turntables, worked by hand or power, makes the distribution of material between the buildings very easy, and it will be noticed that the distance the material will have to travel from any one building to another is comparatively short. At the extreme outer end of each building is another circular track, primarily to be used for shipping purposes, and the distributing of such material as may come in or go out over the connecting railway lines. This track runs through the end of each building; and in such buildings where the machinery, castings, or other goods are to be handled, the heavier travelling crane in that particular building, which should run the length of the shop, can easily unload or load the cars. This arrangement makes it possible to go into every shop without having a multiplicity of tracks and switches, thus cutting up the available yard room, as is usually the case. It is also possible, if there is sufficient ground available, to extend any one or all of the buildings and still retain the best features of the design.



A NOVEL WORKS PLAN

WHILE the recent development of uses for emery wheels in machine shops has been remarkable, and an immense amount of work is done with them today which, a few years ago, would not have been considered practicable, the education of the user is nevertheless far from being complete. In many instances the wheels are doing only a fraction of the work of which they are capable, and that possibly all because they may not be running at proper speed or because they are not best adapted to the particular work in hand. The importance of proper wheel speed is well illustrated by the results of a recent test in which precautions were taken to insure a uniform pressure of the work against the wheel. A piece of steel was cut exactly in half; the wheel was run at 5000 feet peripheral speed per minute, and one of the pieces of steel was ground on the wheel under those conditions. Then the wheel was speeded to 6500 feet peripheral per minute, and under the same pressure the other piece of steel was ground. It was then found that at the higher speed about 2¾ times more metal per cubic inch of emery was ground than at the lower speed, and that, too, in three-quarters of the time.

THE points to be considered in emery grinding were recently summed up as follows by Mr. Charles G. Smith in a paper read before the Pittsburgh Foundrymen's Association:—1. The required condition of the work when finished. Is it to be polished when taken from the machine, or polished by buffing afterward? In the latter case, the number of emery that is used in the buffing must be considered. Then, also, if the material to be ground is tempered or not, before or after grinding. 2. How much stock is to be removed? 3. What is the nature of the material to be ground, cast steel, machinery steel, chilled iron, cast iron, brass, malleable, and is it hard or soft? 4. Are the pieces light or heavy in weight? How much metal is there in the part to be ground to absorb the heat? All these must be considered to ascertain the proper method of performing the work and the grain and grade of wheel to do it correctly. In regard to grain and grade of wheels, the best results, according to Mr. Smith, are always obtained by using as coarse a wheel as possible and as hard as possible, as a coarse, hard wheel, will not fill with metal so easily, and, being hard, will not scratch so deeply. Better results will also be obtained by using wheels of large diameter; the larger the diameter of the wheel, the better the results. In one case of complaint cited by Mr. Smith, he found a small machine in service carrying a 14 or 16-inch wheel with 2-inch face, the machine being bolted simply to the floor, with considerable vibration when running. Substituting a 24 × 3-inch wheel, running at 1000 revolutions a minute, and set on a substantial concrete foundation, made an astonishing difference.

EXEMPLIFICATIONS of engineering principles in living structures were given recently in an interesting address before the Engineers' Club, of Philadelphia, by Mr. Henry Leffmann,—incursions into what he called the borderland of biology and engineering. As one of the simplest examples, Mr. Leffmann cited the instances of the bones of the skeleton, many of which illustrate the well-known principle of the hollow column, resulting in the greatest degree of strength with the least material. The articulation of the bones into the skeleton with movable parts involves the construction of joints and the application of power. The joints are provided with membranes which secrete a lubricating fluid, and, in the case of the human knee-joint, which sustains considerable weight and operates with great frequency and under conditions which involve much strain, an intermediate structure, tough and somewhat elastic, is interposed between the moving surfaces. The general construction of this joint is complicated, and this accounts for the severity of the apparently trifling injuries to it. The joint construction of the elbow

is interesting as exhibiting several forms of motion. The main bone of the forearm, called the ulna, moves upon the articulating socket of the arm bone, the humerus, by means of a hook-like depression, the point of the hook being received into the deep depression at the back of the humerus, so that the outstretched arm is rigid. We may notice an objectionable construction here in the fact that the nerve-trunk supplying a considerable portion of the hand passes directly over the back of the forearm bone beneath the skin, and thus this delicate structure is easily injured by a blow upon the back of the elbow,—the experience of hitting the so-called "crazy-bone."

Mr. Leffmann further pointed out that as many animals and some plants have circulating fluids, we find in them some applications familiar to hydraulic engineers; it is, however only in the higher animals that we find the most striking examples of these principles. The circulatory system, by which anatomists designate the entire series of vessels concerned in the movements of the blood, affords examples of pumps, valves, and pressure equalisers. The heart may be considered as a pair of double pumps. The venous blood is drawn into a chamber on the right side of the heart, called the right auricle, and passes into a second, larger, chamber called the right ventricle, from which it is pumped into the lungs. It returns into the left auricle, passes from there into the left ventricle, and from this into the general circulation. The four chambers are made up of muscular tissue, and act by contraction. There is, therefore, no piston arrangement. The action may be likened, to some extent, to that of the pistonless pumps of the pulsometer variety, the name itself being suggestive. To prevent regurgitation in the successive movements, valves are introduced at different points. The large trunk artery, —the aorta,—by which the blood leaves the heart, bears a close analogy to a large gas or water main, and is divided and subdivided in much the same fashion, the bifurcations being usually, though not always, at acute angles. Nature's make-up, however, is here superior to that of man, in that, normally, there are no dead ends in the system, and the fluid finds exit from every point which it enters, though often through an exceedingly fine network of tubes.

Regarding the fuel value of the eucalyptus tree, Mr. D. E. Hutchins, of Cape Colony, who more than twenty years ago began studying the subject, recently had an article in *Nature* which makes decidedly interesting reading. According to this, it is considered much cheaper in some parts of Cape Colony to plough up the land and plant a forest of quick-growing trees, like the eucalyptus, than to import coal. In 1882 Mr. Hutchins and Sir A. Brandis, as the result of their experiments, discovered that eucalyptus trees planted on tropical mountains produce fuel at the rate of 20 tons,—dry weight at 60 pounds per cubic foot,—per acre per year in perpetuity. The eucalyptus plantation reproduces itself when cut, without further expense, and its dry timber, heavier than coal, has an equal or a higher thermal power, bulk for bulk, than coal. This result was obtained as a measurement of the maximum yield of *Eucalyptus globulus* on the Nilgiris, in Southern India. If a chance tree on a chance mountain in a chance soil can produce the equivalent of 20 tons of coal per acre per year, it seems not unreasonable to suppose, as Mr. Hutchins suggests, that by selection, double this, or 40 tons, can be produced.

A powerful sun, a heavy rainfall, and a very rapid forced growth are the essentials of such a production of wood fuel. A glance over the rainfall map of the world shows that these conditions are fulfilled over about 8,000,000,000 acres of its surface, which is between one-fourth and one-fifth of the total land surface of 35,200,000,000 acres. One-half of this area under forest might thus

yield the equivalent of 160,000,000,000 tons of coal yearly, which is more than 288 times the world's present consumption of coal, assuming that coal and eucalyptus timber are of approximately equal heating power. On the basis of the actual forest yield of the present day, we have half of this, or the equivalent of 80,500,000,000 tons. In Germany one-fourth of the total area is under forest, and taking the German standard of one-fourth forest, on the basis of the present maximum yield, we should obtain 40,250,000,000 tons; while if the maximum forest yield be converted to an average forest yield, there would still remain a yearly product of 20,175,000,000 tons, which is rather more than thirty times the world's present consumption of coal. Thus it would appear that the yield of firewood from the world's tropical and extra-tropical forests, wherever they are fully stocked and scientifically worked, will yield the equivalent of from 30 to 122 times the present consumption of coal, or even up to 243 times that consumption, if the present timber yield be doubled by cultivation. Presuming these figures to be correct, we need not worry much about the exhaustion of the world's coal supplies.

SOME very interesting figures concerning telephone development in the United States were given recently by Mr. C. J. H. Woodbury, one of the officers of the American Bell Telephone Company, in an address delivered before the Underwriters' Club, in the city of New York. According to these, the length of line built and maintained by the companies operating the Bell system averages 3.29 miles to each instrument, and, excluding the long-distance lines, 50 per cent. of the wire is underground. When a call is made, the average amount of line placed at the disposal of the person who makes it is 6.58 miles. That anything like intercommunication is possible becomes the more a cause for wonder when it is remembered that the modern switchboard is a marvel of complexity in design and construction. It is the evolution of a quarter of a century, resulting from the collaboration of many experts. Its mechanical intricacy will be better appreciated when it is remembered that, even with the advantage of modern machinery and skill in manufacture, it requires as long to build and install a switchboard as to build and equip a merchantman for foreign trade, the time being from a year to two and a half years, and the cost varying from $500 to $600 per square foot for the smaller installations adequate for cities of 50,000 inhabitants, to $1200 per square foot for the larger switchboards. The central station equipment, however, is but a small part of the whole cost of a telephone system, although it represents the greatest concentration of value in relatively small space. The life of a switchboard is usually short. Constant repairs, replacements, and extensions rapidly deteriorate it, and the effect of wear is distanced by the more rapid progress of invention and improvement. In a few years it becomes obsolete.

THE Bell telephone system provides for 9,322,951 calls per day, or nearly 2500 calls a year originating at each telephone in service. As one telephone is called for each one used, the average employment of each telephone in use is 5000 times a year. When one uses a long-distance telephone, a large amount of property is placed at his service. For example, speaking from Boston to Omaha, a distance of about 1400 miles, as one business concern does every morning, the apparatus used, at the present price of copper, represents an investment of over $283,000, and it requires the service of nine skilled operators to make the necessary connections. The weight of the copper wire in the connection is 1,131,000 pounds, or 565½ tons, and it seems very like a miracle that the human voice can cause this immense mass of metal to vibrate in unison throughout its several parts, even to the delicate shades of tone which distinguish one voice from another, and that the instrument at the end is so sen-

sitive that it can catch and repeat these vibrations and transmute them into articulate speech. And it is all so new. Less than thirty years ago the telephone was an "over-capitalised" dream, and the stock of the Bell Company could scarcely be quoted low enough to find a purchaser. Twenty years ago it was the luxury of the rich. What it has become in the past ten years we can best appreciate by reflecting what would happen if for any reason the telephone lines should be put out of use for a week.

In criticising recently, before the American Society of Mechanical Engineers, some of the features of current machine tool design, Professor John E. Sweet made the point, among others, that milling machines of the planer style are constructed like planing machines, seemingly with the thought that the conditions are identical, while they are not. If the bed of a planing machine and the table were of the same length, the weight of the table and the load overrunning the end of the bed would soon wear the top of the bed crowning and the under side of the table concave to fit, and it is to counteract this tendency of gravity to wear them out of true that the beds are made longer than the tables. With the milling machine the load is less, more of it in the middle of the table, because there is less gained by putting on small pieces end to end, and the down pressure of the big cutter, always in the middle partially, if not wholly, neutralises the tendency to wear out of true by gravity. When such a machine has side cutters or a vertical spindle, the pressure is always in the middle, first in one direction and then the other, exactly the reverse from the gravity action, and instead of the side guide of the bed being longer than the table, it should be shorter by just about the same amount as the bed of a planer needs to be longer. Many times the sliding piece and its guides can be the same length and keep straight. The things which do not tend to wear out of true do not wear much, and the things which do wear out of true and have to be refitted are never just right but when new and when so refitted. Where a short block slides on a long guide, if the scraper marks wear out sooner along the middle than at the ends, the ends of the guide need cutting off, however much overrun it may give to the sliding block.

As illustrating the remarkable penetrative powers of radium rays, Mr. George F. Kunz, in a recent address at the American Museum of Natural History, told of the following experiment:—Radium of 300,000 activity was placed in a sealed glass tube contained in a rubber thermometer holder, the top of which was tightly screwed to prevent emanations of any kind to pass through the joints, and the whole was placed in a water-tight tinned-iron box. Over this box were placed, first, a heavy silver tureen, 1-16 inch thick, then four copper plates, such as are used for engraving, and finally a heavy graduated measuring glass, 10 cm. in diameter, filled with water to a depth of 6 inches. A diamond was then suspended in the water and became phosphorescent immediately. Whenever the tube with radium was withdrawn a distance of more than 2 or 3 feet, the phosphorescence ceased, ever to be resumed on replacing the radium under the tureen. This experiment shows that the active power of the radium penetrated, successively, glass, rubber, silver 1-16 inch thick, four copper plates, glass ¼-inch thick, and finally 3 inches of water. No other known substance or agent, whether it be light or electricity, possesses any corresponding power of penetration.

A steel chimney stack, while in full blast, was successfully extended not long ago in Indianapolis by W. H. Schott, a Chicago engineer. According to an account of the operation given in *The Iron Age*, the Century Building in Indianapolis had a stack that reached only as high as the roof of an adjoining new

building, the height of this structure not only interfering seriously with the draught of the Century plant, but the smoke from the latter, under certain conditions, also pouring into the windows of the upper stories of the taller building. The difficulty in the way of adding to the height of the chimney lay in the fact that it was out of the question to bank the fires of the Century Building plant; the work had to be done while this plant was in full operation. Mr. Schott, who had put in the plant in the first place, solved the problem by cutting large port holes in the top course of the stack and then plugging up the opening at the top. Suitable scaffolding was next erected, and a gang of boilermakers was set to work rivetting on extension sheets. In this way, in eight days, 60 feet of 3-16-inch stack, 6 feet in diameter, were added to the old stack.

FRANCIS B. ALLEN

Second Vice-President of the Hartford Steam Boiler Inspection & Insurance Company

A BIOGRAPHICAL SKETCH

FOR over thirty years Mr. Francis B. Allen has been closely identified with the work of the Hartford Steam Boiler Inspection & Insurance Company, at present as its second vice-president, and in that period has become widely known as an able exponent of those principles of boiler engineering which have been at the foundation of the remarkable success. of this company.

Mr. Allen comes of military stock, his great-grandfather having been a soldier in the Revolutionary War, and his grandfather in the War of 1812. In 1861, at the age of twenty, he entered the United States Navy as assistant engineer, with the rank of ensign, and was ordered to the United States gunboat *Port Royal*, attached successively to the Potomac and James River flotillas, East Gulf and West Gulf Squadrons. Promoted to a junior lieutenancy, he was transferred to the ironclad ram *Dictator*, of the North Atlantic Squadron, and after a year's service on this vessel he was detached and ordered to the Novelty Iron Works, of New York City, where for two years he was engaged as one of the detail engineer officers conducting steam expansion experiments under the direction of Chief Engineer B. F. Isherwood, of the United States Navy. In 1867, upon the completion of these experiments, Lieutenant Allen was ordered to join the United States flagship *De Soto*, of the West India squadron, and the following winter he tendered his resignation from the naval service and entered civil life.

After serving the Northern Pacific Railroad Company for a season as assistant to its superintendent of motive power Mr. Allen, in 1872, became the special agent of the New York department of the Hartford Steam Boiler Inspection & Insurance Company. In 1882 he was promoted to the position of supervising general agent in the home office, and moved to Hartford, Conn., and in 1888 he was made second vice-president of the company. His department includes the general supervision of the company's business in the field and the superintendency of its agents. The duties involved are most arduous, and require special skill and adaptation to the work, both of which Mr. Allen possesses in a remarkable degree. He is devoted to the interests of the company, where he enjoys the utmost confidence of his associates.

PHOTO BY AMES, NEW YORK

LEWIS BUCKLEY STILLWELL

ELECTRICAL DIRECTOR OF THE INTERBOROUGH RAPID TRANSIT COMPANY, NEW YORK

SEE PAGE 383

CASSIER'S MAGAZINE

VOL. XXV FEBRUARY, 1904 No. 4

THE WAR FLEETS OF JAPAN AND RUSSIA

By Archibald S. Hurd

No better reason need be given for the large amount of space devoted in this issue to the war fleets of Japan and Russia than the events of the past few months. War in this instance has been largely provoked by commercial considerations,—those of industrial engineering in a sense,—and it is the shaping of these in which the world at large will be primarily interested and in which the naval equipments of the warring nations will play the most important part.—THE EDITOR.

JAPAN'S NAVAL STRENGTH

FLEETS are the outward expression of national policy. Behind each of the modern fleets of the world lies some distinct aim, and in many cases it is objective and not merely subjective. The navy of Japan is a force full of meaning to those who will take the trouble to study its genesis and development. It is a short story, and it is one in which Englishmen and Americans have a special interest.

Great Britain gave to Japan her first steamship, a yacht known as the *Empress*, which Lord Elgin, when negotiating the first commercial treaty, that of 1858, took out with him as a present to the Emperor from Queen Victoria. At that time the Japanese fleet consisted of a number of square-sailed junks, and the people who had managed to defend their shores successfully with these craft, had no conception that they required anything better. The *Empress* was a vessel of 400 tons; but it was useless to the recipient, for he was not permitted by the constitution to go afloat. Consequently, the advent of this little yacht in Japanese waters, though it opened the eyes of the people to the use of steam, did not work an immediate revolution.

Eight years passed before Japan rose to the resolve to possess a real warship, and then it was from the United States, and not from Great Britain, that she made her purchase. She bought from America the small ironclad, the *Stonewall Jackson*, a ship of only 1300 tons displacement, but armed with ten 10-inch guns and some smaller pieces. She was 157 feet long, with a beam of 26 feet and a draught of 13 feet, and had twin screws. With 700 indicated horse-power, she was credited with a speed of 9 knots. Built of wood, she had a belt of iron, 4 inches thick, and

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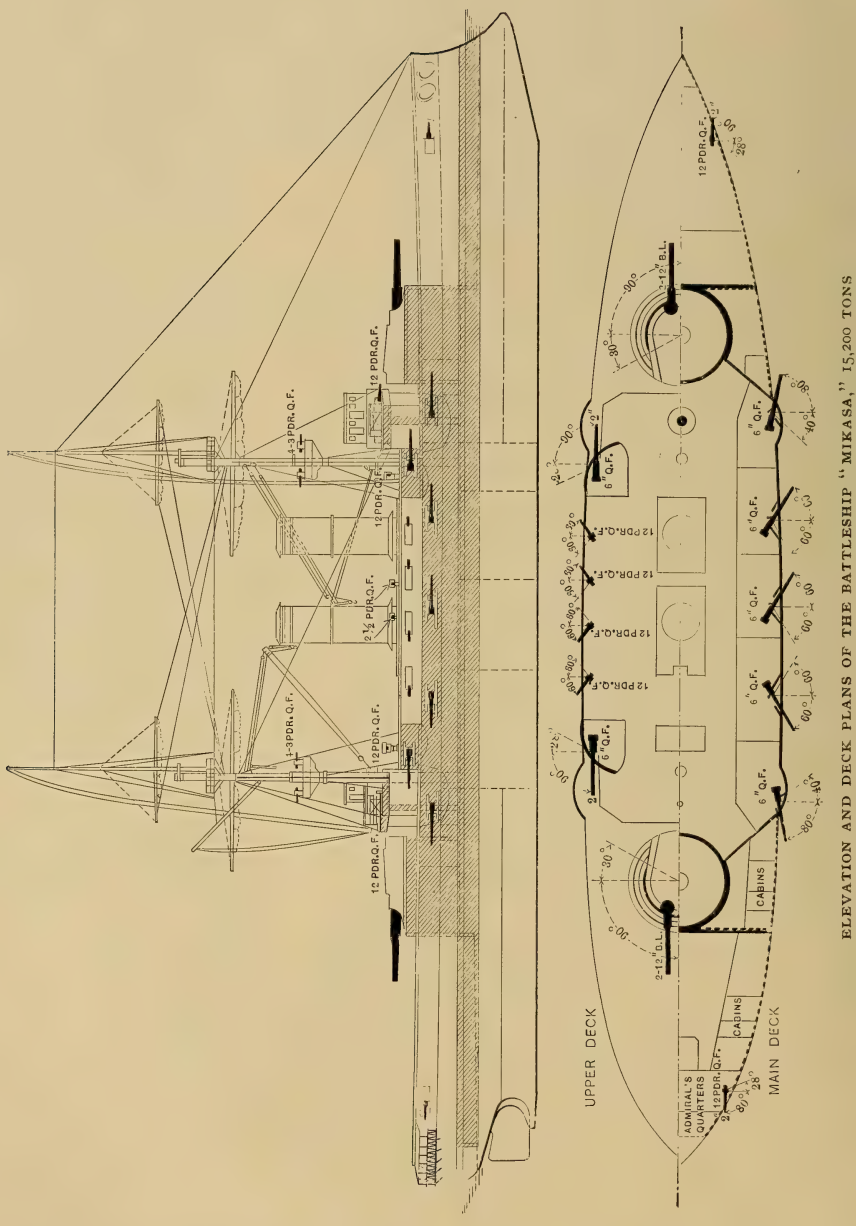

ELEVATION AND DECK PLANS OF THE BATTLESHIP "MIKASA," 15,200 TONS

WORKING A 12-POUNDER ON THE "IWATE"

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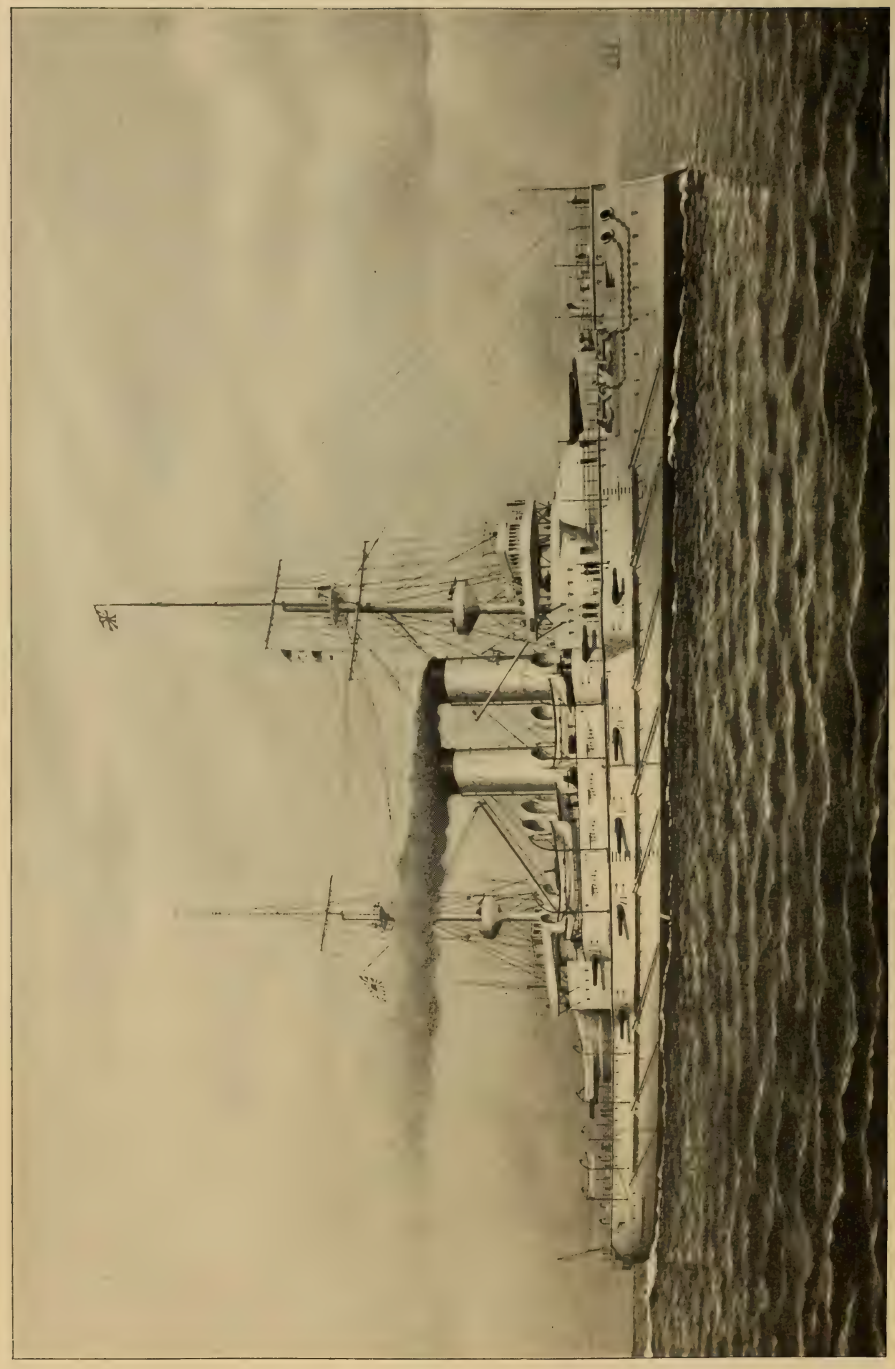
the battery was protected by armour of the same thickness. In these days she would be classed as a gunboat; then she was regarded as a powerful ship of war, and for over ten years she was the only ironclad owned by Japan.

In 1878 Japan commissioned Sir Edward Reed to design a battleship, and the *Fu-Soo*, built on the Thames and launched in 1877, was the result. She was of nearly three times the size of the *Adsuma*, as the *Stonewall Jackson* had been renamed, and had then four 15-ton Krupp breech-loaders, two 6-ton weapons, six light pieces, and five machine guns. With a speed of 13½ knots, she was far and away the most powerful ship of war in adjacent waters, for at that time China had but one armoured gunboat of 195 tons, a wooden craft with one 6-ton gun, and even Great Britain had only within the past ten years established her China Squadron, and this comprised not a single battleship. Other powers were, for the most part, not represented in those waters. Japan had no occasion for uneasiness, and for some time she was well content with her position as the nation supreme afloat among those washed by the waters of the Pacific. In addition to the *Fu-Soo*, she acquired before 1880 three small armoured ships, the *Kongo*, *Hi-Yei* and *Rinjo*, built in Great Britain, vessels of just over 2000 tons each, but well armed for their size. As late as 1885 she had added only one more ironclad to her fleet, but she had a number of cruisers.

In the following ten years little attempt was made to increase this small ironclad fleet, though in the meantime China had made some powerful additions to her navy, and the shadow of war was already present. China was being drilled by a British admiral, Rear-Admiral W. H. Lang, while Japan was in the hands of other British officers, of whom more must be said later. China



THE BATTLESHIP "MIKASA," BUILT BY MESSRS. VICKERS, SONS & MAXIM, LTD., BARROW-IN-FURNESS, IS THE MOST POWERFUL AND THE BEST EQUIPPED MAN-OF-WAR OF HER SIZE AFLOAT. SEE PAGE 301

possessed two battleships of 7430 tons each, and two others of 2800 tons each, in addition to a large and powerful coast defence ship, an armoured gunboat and over twenty cruisers.

Japan had only the armoured ships already mentioned, fourteen cruisers and some small craft. On paper, she was inferior in strength to China. On the eve of the war she awoke to the need for sea power, and ordered two battleships, the *Fuji* and the *Yashima;* but the orders were given too late, and Japan entered on the contest with China in 1894 with weaker naval forces, but with high courage and a light heart. The confidence of the Japanese Navy in itself was fully justified, and the victorious war served to open the eyes of the nation to the true value of sea power.

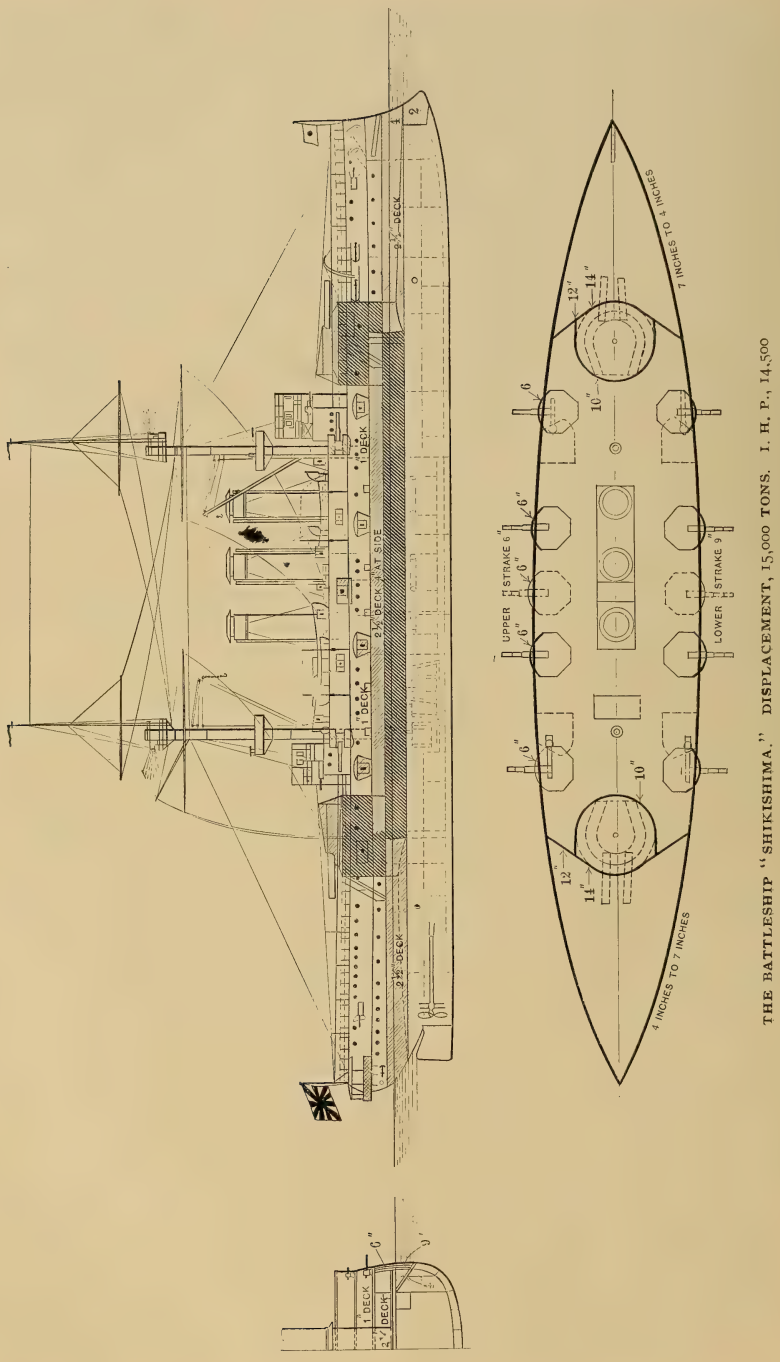
Down to the beginning of hostilities the Japanese had placed little reliance in the fleet. It was regarded as the toy of the aristocratic class who had so long ruled the country, and every yen which was expended on it was grudged by a large section of the nation. The people failed to foresee their destiny. They could not appreciate the importance to such a community, living on a number of islands, of an adequate navy to defend its interests and to win colonial possessions in which the teeming population of the Japanese islands could settle with a wider outlook and a better chance of remunerative employment. But the result of the war, the splendid achievements of officers and men against considerable odds, carried conviction to the hearts of the people, and Japan was set on the road of naval aggrandisement even before Russia, with the assistance of Germany and France, came on the scene to drive deep the lessons of the war.

Japan had defeated China and had arranged the terms of peace when the Muscovite power came between the victor and the vanquished, and, in the name of the integrity of China, told Japan that she could not hold Port Arthur, which she had gained at the point of the sword. Japan found herself in grievous peril, threatened, as she was, by three of the great war nations of the western world, and she realised in the next few weeks two substantial facts,—first that she had to relinquish her claims to Port Arthur and be satisfied with Formosa and the indemnity which had, already, been bargained for, and secondly that she owed even the slight consideration she received to the friendly offices of the British and Americans, who refused to join in the coercion of the victor.

Within three years Russia was in possession of Port Arthur, and by 1900, in virtue of the concessions for railways which she had obtained from China, her troops, nominally to guard the railways during the Boxer troubles, had overrun the whole of Manchuria, where they have remained. This sequence of events revealed to the Japanese the true gravity of the situation; the youngest of the nations, claiming an equality with the older nations of the west, she found herself more or less isolated, and meantime the world was gathering its men-of-war round the sick man of the Far East.

Out of her war with China, Japan emerged with three main lines of policy,—first, to hold what she had obtained, which required a great fleet; second, to acquire colonial outlets for her teeming population, which again required a great fleet; and third, to take China in hand as her friend and teach her the lessons Japan has learnt from the western nations, foremost among which was the relation between sea power and independence. An independent China meant that Japan would be saved from many of the dangers from which she suffers to-day now that the great naval powers of the west, and particularly Russia, have got footholds in the Chinese Empire. Under these circumstances, Japan, at the end of the war, determined to devote the whole of the Chinese indemnity, and more besides, to the upbuilding of a fleet to secure her position in the Pacific.

The history of the Japanese Navy covers fewer years than that of any other naval force in the world. Within living memory she had no ships beyond the old square-sailed junks, the secret of the



THE BATTLESHIP "SHIKISHIMA." DISPLACEMENT, 15,000 TONS. I. H. P., 14,500

design of which had been learnt from the Dutch, those one-time masters of the lore of seamanship. As has been explained earlier in this article, her progress in material was not fast, but she was wise in her procedure. She realised that training for her officers and men was of infinitely more importance than a great array of modern ships, and that it was the highest wisdom to educate no armoured men-of-war of any account; yet she beat China.

The birth of the Japanese fleet may be said to date from 1872, when the present Vice-Admiral Sir Archibald Douglas, the first Canadian officer to rise to high rank in the British Navy, was selected to proceed to Japan in command of a naval mission which was organised at the request of the Japanese

A SIAMESE BAND WITH AN ENGLISH BANDMASTER

first a personnel to take care of, and to fight to the best advantage, the fleet which was to be created.

Other nations had gone on an entirely opposite policy and had courted disaster. China had built many powerful ships, but when the day of trial came, it was found that these formidable weapons were of little use because they were in the hands of men who, for the most part, lacked the training requisite in a naval sailor. Italy learnt the lesson after Lissa, and other countries have paid a great price for this knowledge. Therefore, Japan showed no undue haste in filling her harbours with modern ships, and, as late as the war, had

Government. The new nation went to France and Germany for tuition in the science of warfare on land, but turned to the supreme naval power of the world for advisers in the creation of its fleet. At that time Sir Archibald Douglas held the rank of commander, and was recognised by the British naval authorities as one of the most talented officers of the fleet. As a lieutenant he had served for three years and a half as senior staff officer of the *Cambridge*, the gunnery school ship at Devonport, where the men of the western port go through their course of training in gunnery. After his promotion his scientific attainments led to his selection as instructor

OFFICERS OF THE "IWATE." A TYPICAL GROUP

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in the use of the Harvey torpedo in the Channel fleet.

It was this young commander, typical of the new school of naval officers, which mechanical research as applied to naval warfare was causing to come to the front, who was chosen to go to Japan and lay the foundations of the modern fleet of that country. Admiral Douglas eventually served as director of the Imperial Naval College in Yeddo for two years, and on relinquishing this position received the thanks of the Emperor and the approval of the British authorities. Another officer who had a part in this work in Japan is Vice-Admiral Sir Arthur Wilson, V. C., who is now commanding the Home fleet, while as late as the eve of the war with China Admiral James Ingles remained in Japan as adviser of the Japanese Government in the development of the fleet.

Simultaneously young Japanese officers visited Great Britain, and were appointed to British men-of-war and studied in British naval institutions, so as to become thoroughly familiar with the ins and outs of the system upon which the British fleet is managed. By these means were the foundations well and truly laid of the naval organisation of Japan. Slowly also dockyards and educational establishments were created. The country has been divided into five maritime districts, with headquarters at Yokosuka, the chief building yard; Kuré, where an armour plant is now being laid down; Sasebo and Maizuru; while docks and barracks are to be constructed also at Muroran. All these arsenals are well defended,—practically impregnable.

Japan came out of the ordeal of the war with China with all the honours possible. In fact, the Japanese officers and men have run great peril of being demoralised by over-much praise. When they met and vanquished the Chinese, the world rang with the reports of their daring exploits, dashing bravery, and steadfast endurance. They come of a stock which has been accustomed to fighting, and to whom the sea is a stern mother, for in few parts of the world are the waters so treacherous and the coasts so dangerous. It can be truly said that the average Japanese officers and sailors do not know what fear is. A grim courage is allied to a keen intelligence, and by the institutions which have been set up, both have been trained to excellent purpose, the courage robbed of its mere impetuosity, and the intelligence directed to actual war training. No one who is familiar with the Japanese personnel to-day doubts that while it retains all the sterling qualities that distinguished it at the time of the war, it has reached a higher plane in technical efficiency. The fleet has in all two admirals, nine vice-admirals, twenty-five rear-admirals, sixty-five captains, 119 commanders, 167 lieutenant-commanders, 220 lieutenants, and 305 sub-lieutenants. The engineering, medical, and other officers and 31,688 seamen ratings of different grades bring up the total of the fleet to 35,355 men.

As to the material of the Japanese Navy, it has already been mentioned that after the war with China a large shipbuilding programme was taken in hand, most of the orders for new men-of-war being placed with British firms. Certain unarmoured cruisers and torpedo craft have also been built at Yokosuka. With the old programme completed, a lull occurred, not because it was not fully realised that more ships were necessary in view of the increased activity of Russia, but because the political parties in Japan were not able to come to an agreement as to the method of raising the necessary funds. On the one hand, it was desired to secure it by taxation, and, on the other, a loan was advocated. The last-named suggestion has been at last adopted, and the programme will be put in hand at an early date. Most of the large armoured ships, it is anticipated, will be built in Great Britain.

In the meantime it will not be uninteresting to indicate the present strength of the Japanese fleet. The large ships, completed for sea since the Chino-Japanese war, are indicated by an asterisk in the tabulated statement on pages 296 and 297.

Japan also possesses a number of

THE PRESENT STRENGTH OF THE JAPANESE FLEET

BATTLESHIPS

First-Class (six ships)

Name	Date of Launch	Displacement. Tons	Armament	Speed, Knots	Maximum Coal Capacity. Tons
* Mikasa	1900	15,200	4 12-in. 14 6-in. Q. F. 40 smaller guns	18.6	1,690
*Hatsuse	1899	15,000		19	1,690
*Asahi	1899	15,200		18	1,360
*Shikishima	1898	15,000		18.6	1,360
*Fuji	1886	12,450	4 12-in. 10 6-in. Q. F. 24 smaller guns	19	1,300
*Yashima	1896	12,300			

Second Class (one ship)

Chin Yen (captured from China)	1881	7,220	4 12-in. 4 6-in. Q. F. 10 smaller	14	1,000

COAST DEFENCE VESSELS (TWO SHIPS)

(Armoured ships which cannot fight at a distance from a base)

Hei-yen (captured from China)	1888	21,067	1 10 2-in 2 6-in. 8 smaller	11	350
Fu-Soo (the first armoured ship built for Japan)	1877	3,717	4 9.4-in. 4 6-in Q. F. 15 smaller	11	360

CRUISERS

Armoured (seven ships)

*Iwate	1900	9,750	4 8-in. Q. F. 14 6-in Q. F. (12 only in Yakumo and Asumo) 20 smaller (19 only in Asama and Tokiwa)	21.3	1,200 to 1,600 equal to 7,000 to 10,000 miles at economical speed
*Idsumo	1899	9,750		21	
*Yakumo	1899	9,850		20	
*Asumo	1899	9,400		20	
*Asama	1898	9,700		23	
*Tokiwa	1898	9,700		23	
Chiyoda	1890	2,450	10 4.7-in. Q. F. 17 smaller	17.5	420

Protected: First-Class (none)

Protected, Second-Class (twelve ships)

*Chitose	1898	4,898	2 8-in. Q. F. 10 4.7-in. Q. F. 18 smaller	22.5	1,000 equal to ab't 4,000 mls. at 10 knots
*Kasagi	1898	4,784		22.5	
*Takasago	1898	4,180		23	
Akitsushima	1892	3,100	4 6-in. Q. F. 6 4.7-in. Q. F. 12 smaller	19	500
Yoshino	1892	4,180	4 6-in. Q. F. 8 4.7-in. Q. F. 22 smaller	23	1,000
Hashidate	1891	4,210	1 12.5-in. 11 4.7-in. Q. F. 19 smaller	17	405
†Matsushima	1890			17.5	
Itsukushina	1889			17	
Naniwa	1885	3,727	8 6-in. Q. F. 16 smaller	18.7	800 equal to 9,000 miles at 13 knots
Takachiho	1885	3,727	2 10.2-in 6 6-in. Q. F 16 smaller	18.7	
*Tsushima	1903	3,365	6 6-in Q. F. 14 smaller	20	600
*Niitaka	1902			20	

(† Matsushima has 12 4 7-in. and only 16 smaller guns)

small vessels, including seven gunboats of 320 to 640 tons each, heavily armed, and six coast-defence gunboats, each mounting one 11-inch Armstrong gun and two 12-pounders, and carrying 60 tons of coal. These were captured from China in the war. They were all built at Elswick in the period from 1879 to 1881.

Such is the fleet possessed by Japan, and it must be confessed that it forms an impressive array of fighting strength for the youngest of the great powers. All the battleships are Britsh-built, and the same is true of the armoured cruisers, with the exception of the *Yakumo*, which was built at the Vulcan Company's works at Stettin, Germany, and the *Azuma*, which was constructed at St. Nazaire, France. The firms of Yarrow and Thornycroft have built most of the destroyers; but some of the later ones are the workmanship of the dockyard at Yokosuka, which is also responsible for several of the smaller cruisers.* The torpedo-boats have been built by Messrs. Normand, Schichau, and Yarrow, and many others have been en-

* Descriptions of the *Shikishima*, the armoured cruisers and torpedo craft were given by Rear-Admiral C. C. P. Fitzgerald in CASSIER'S MAGAZINE of August, 1900. To this it may be interesting to refer in connection with the present article.—THE EDITOR.

THE PRESENT STRENGTH OF THE JAPANESE FLEET—(*Continued*)

Protected, Third-Class (*seven ships*)

Name	Date of Launch	Displacement. Tons	Armament	Speed, Knots	Maximum Coal Capacity. Tons
*Akashi	1897	2,657	2 6-in. Q. F. 6 4.7-in. Q. F. 16 smaller	20	600 equal to over 10,000 miles at 10 knots
*Suma	1895			20	
Izumi	1883	2,920	2 10-in. 6 4.7-in. Q. F. 14 smaller	17.4	600
Sai-Yen (captured from China,)	1883	2,264	2 8.2-in. 1 6-in. 14 smaller	14.5	230
Hi-yei	1887	2,248	3 6 7-in 6 6-in. 8 smaller	12.5	----
Kongo	1877				
*Otawa	Bldg.	2,600	not known	----	----

Unprotected (*nine ships*)

Takao	1888	1,750	4 6-in. 1 4.7-in. 9 smaller	15	300
*Miyako	1897	1,800	2 4.7-in, Q. F. 10 smaller	20	350
Yaeyama	1889	1,583	3 4.7-in. Q. F. 8 smaller	20	----
Musashi	1886	1,478	2 6.7-in.	13	----
Katsuragi	1885		5 4.7-in.		
Yamato	1880		7 smaller		
Tenriu	1883	1,540	1 6 7-in. 1 6-in 4 4.7-in. 6 smaller	12	256
Kaimon	1882	1,345	1 6.7-in. 6 4.7-in. 6 smaller	10.5	180
Tsukushi	1882	1,370	2 10-in. 4 4.7-in. 7 smaller	16.5	300

Torpedo Vessels (*two*)

Tatsuta	1894	850	2 4.7-in. Q. F. 4 smaller	21	188
Chihaya	1901	850		21	200

Torpedo Boat Destroyers (*nineteen*)

Seventeen built and two building. Speed, 30 to 32 knots

Torpedo Boats (*eighty-five*)

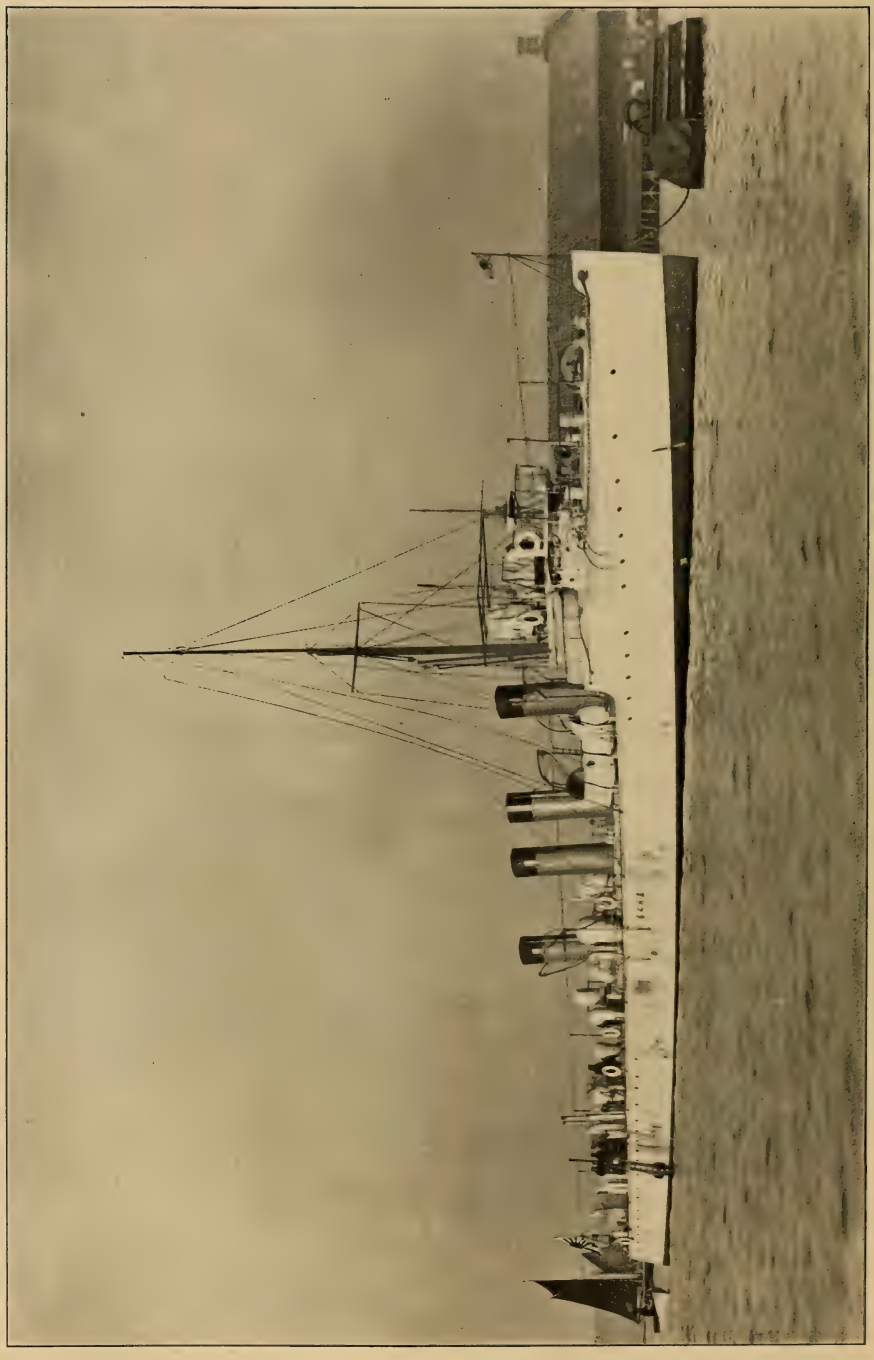
7 Divisional, 11 others building; 80 to 203 tons displacement
33 First-class, 7 others building
27 Second-class, 52 tons displacement

Submarines (*none*)

trusted to the staff at the Kuré and Nagaski yards. The latter, though not a government establishment, has an excellent shipbuilding plant under the oversight of Europeans, where many merchant ships are put together.

The development of battleship design in the Japanese fleet is worth consideration. Japan began her new battle fleet by copying, in the case of the *Fuji* and *Yashima*, the British *Royal Sovereign*, the type of Sir William White, that revolutionised naval construction in some respects; but they sanctioned improvements which were suggested by Mr. Philip Watts. In 1898-99 three more ships were launched, the *Shikishima* at the Thames Ironworks, the *Hatsuse* at Elswick, and the *Asahi* at Clydebank, and these proved to be replicas in general outline of Sir William White's *Majestic* class, but with a different arrangement of the armament,—two more 6-inch guns and four more of the 3-inch calibre; the absence of the single above-water torpedo tube was another conspicuous variation. At the time they were launched, these three vessels were as fine ships as any in the world.

Interesting as these men-of-war proved as modified models of the British design, the Japanese were not so self-satisfied that they would believe nothing better could be designed, and in the last ship of the programme, built by Messrs. Vickers, Sons & Maxim,



ONE OF THE JAPANESE TORPEDO BOAT DESTROYERS. BUILT BY MESSRS. JOHN I. THORNYCROFT & CO., LTD., LONDON

THE CRUISER "TAKASAGO," 4160 TONS. SPEED 22.5 KNOTS

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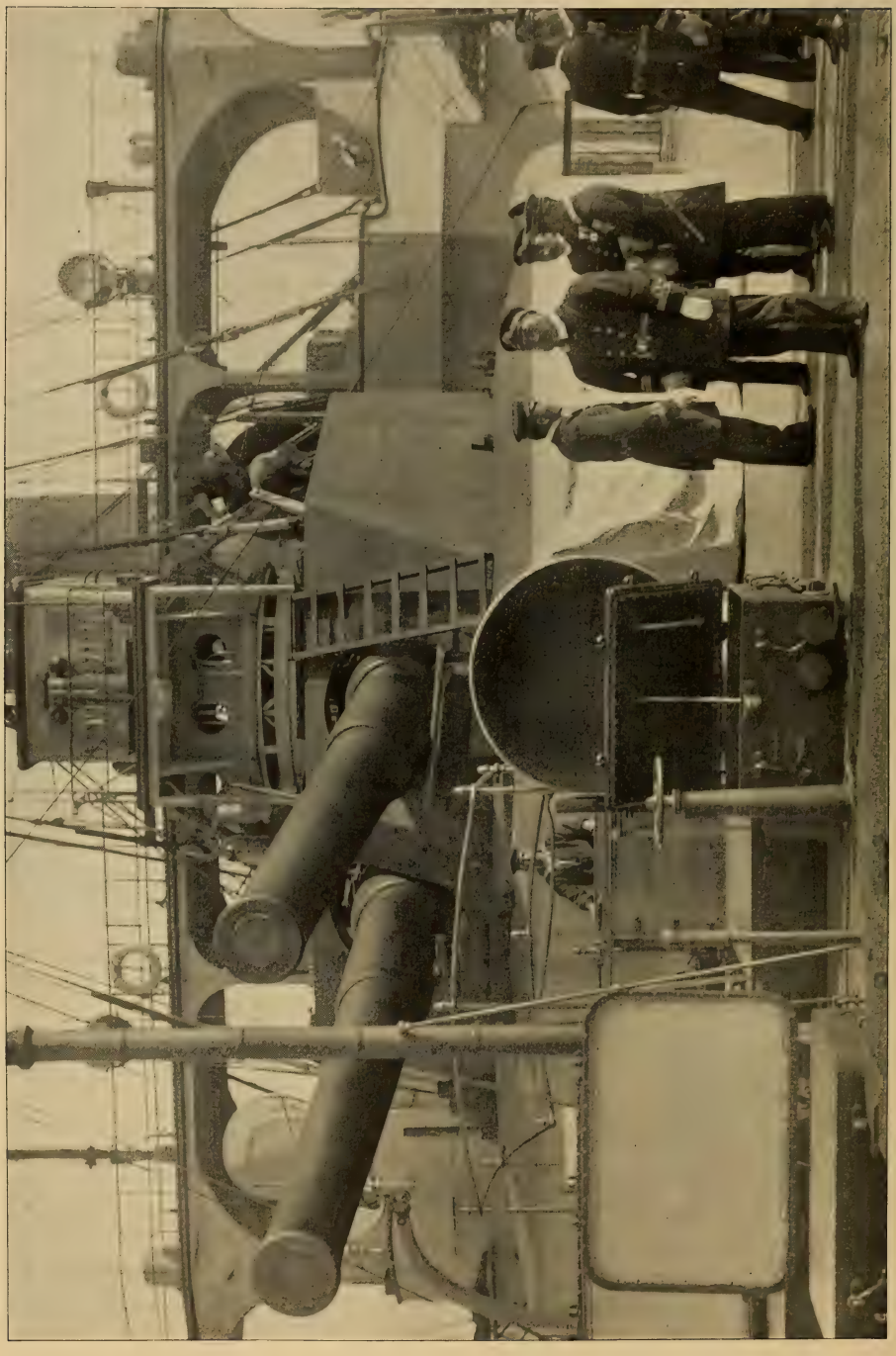

ON THE QUARTER DECK OF THE "ASAHI"

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Ltd., some revolutionary features were introduced. As in the *Asahi*, *Shikishima*, and *Hatsuse*, the *Mikasa* was given a complete armour belt from end to end, an improvement which would have been impossible a few years ago on 15,200 tons displacement without other sacrifices, owing to the weight of the armour then in use. In the *Mikasa* this movement towards an increase in the protection afforded to the ship went a step further. This vessel was designed by Mr. James Dunn, of the Barrow-in-Furness yard, who, like almost all British warship designers, received his early instruction at a government dockyard. As a young man he was associated with the construction of the battleship *Warrior*, the first ironclad in the British fleet, and the *Achilles*, the first to have a complete armour belt.

In the *Mikasa* he also designed a complete belt, but he carried the protection to the upper deck, so as to afford shelter for the 6-inch guns of the secondary battery. This was the first battleship built in a British yard for many years without casemates with their patches of armour for the secondary guns, and it marked a revolution in the world's navies. This principle of the battery in place of the casemate has been adopted not only in the *King Edward VII.* class, but in the gigantic United States ships of 16,000 tons and in those of Russia.

The *Mikasa* is the most powerful and the best-equipped man-of-war of her size afloat, and the Japanese have every reason to be proud of this addition to their fleet. Her main features may be thus indicated:—

Displacement	15,200 tons
Length	400 ft.
Beam	76 ft.
Mean draught	27¾ ft.
Armament—	
Four	12-in.
Fourteen	6-in Q. F.
Twenty	3-in 12 pounders Q. F.
Six	3 pounders
Six	2½ pounders
Torpedo tubes, 18-in., 4 submitted.	

Armour, Krupp principle	
Belt, amidships for 156 ft. rising 2½ ft. above the water line	9-in.
Belt ends	4-in.
Side above belt	6-in.
Deck, on slopes	3·4½-in.
Barbettes	14-in.
Main Bulkheads	12-in.
Casemates for four 6-in. guns and Battery	6-in.
Fore Conning Tower	14-in. with 12-in screens
After Conning Tower	3-in.

Such in summary is the ship which was laid down in 1898 at Barrow-in-Furness. In the protection of her guns she marked a revolution, the import of which was hardly recognised in Great Britain at the time, but was noted and commented upon at length by the United States naval attaché in London, who wrote to the Intelligence Department at Washington in the following terms in description of the battery system embodied in the *Mikasa*:—

"The extension of the main belt to the upper instead of to the main deck, as in preceding ships, dispenses with the necessity for casemates for the 6-inch guns on the main deck; but to insure the same measure of isolation for the ten 6-inch quick-firing guns placed on this deck as is obtained by the casemate system, bulkheads are placed between the guns, while an armoured screen extends the whole length of the citadel behind the guns, as shown on the half plan of the main deck (see page 288). These divisional bulkheads and the armoured screen are of hardened steel, sufficient to insure that the splinters of any shell which may explode in one compartment will not affect either the gun or gunners in the adjoining compartment. The 6-inch guns on the upper deck, four in number, are within 6-inch casements.

"The citadel comprises the chief departure from ordinary practice in the design of this ship, as, besides protecting the space between the belt and the main-deck battery, it takes the place of the ordinary arrangement of casemates usually found in foreign battleships, and entirely protects the 6-inch guns on the fighting deck. The advantage of this arrangement over casemates will be seen when it is considered that throughout the whole of the central portion of the ship the crew is protected from injury while working the guns, while the gun positions themselves are quite as well

protected in front as in the casemates arrangement, and are much less vulnerable in the rear, where they are now protected by the 6-inch armour on the opposite side of the ship, as well as by the thick steel bulkheads which divide the gun positions one from another."

As to the other features of the ship, it may be added that the protective deck is of a minimum thickness of 2 inches and extends over the full length of the ship, but is increased to 3 inches on the sloping parts within the citadel, and to 4½ inches in thickness in the wake of the barbettes. In addition to this, the upper deck within the citadel is made of 1-inch plates.

With reference to the main and secondary armament, the four 12-inch, breech-loading guns are fitted in pairs in the two barbettes on the upper deck, and of the fourteen 6-inch, quick-firing guns, four are placed within casemates situated on the upper deck at the corners of the citadel, the remaining ten 6-inch guns being placed in the box batteries on the main deck. The weight of metal discharged in one minute is 10 tons, representing a striking energy of 802,000 foot-tons.

The *Mikasa* has a speed of 18.6 knots under natural draught, and a coal capacity of 1690 tons, giving her a radius of action of 9000 sea miles at 10 knots speed. Her engines are of the triple-expansion, three-cylinder type, the diameters of the cylinders being 31 inches, 50 inches, and 82 inches, respectively, the stroke being 48 inches. The boilers are of the Belleville type. The total weight of the machinery is 1355 tons.

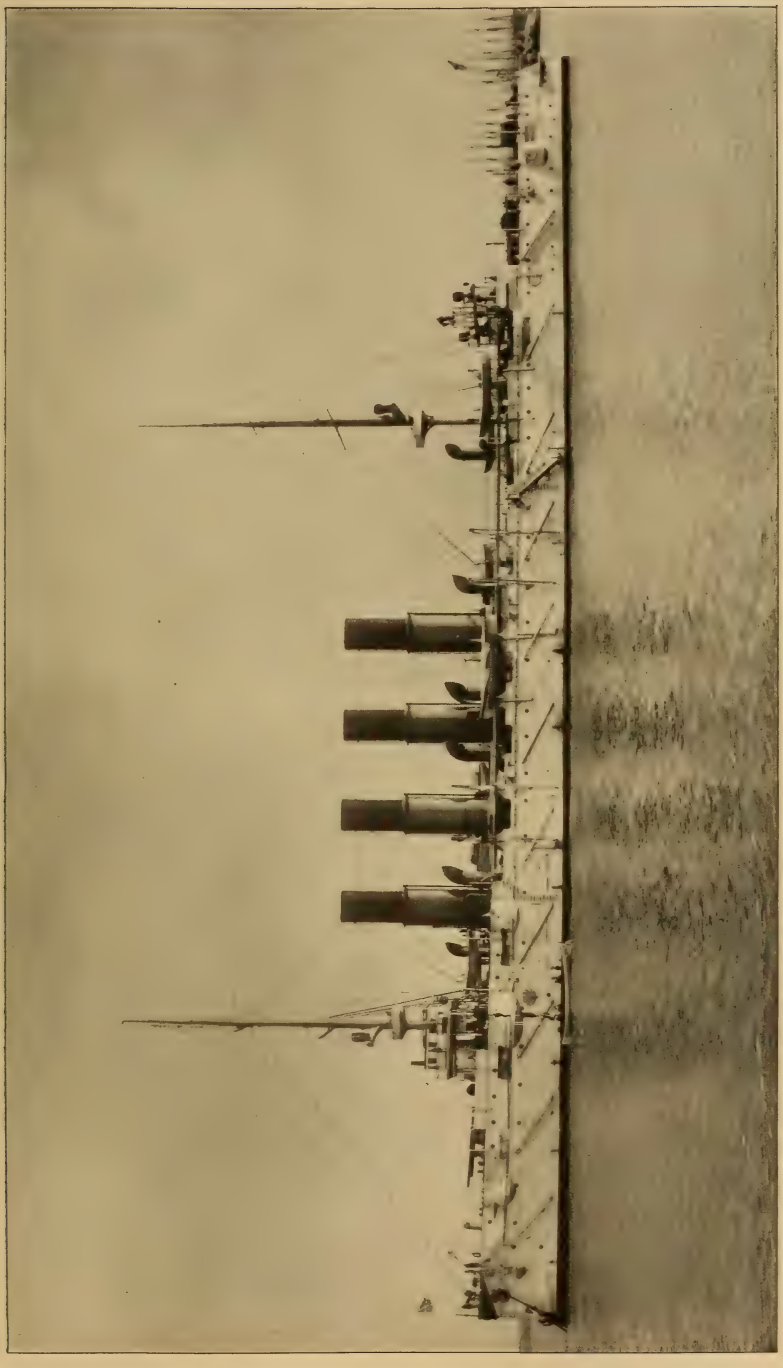
RUSSIA'S FOUR FLEETS

The navy of Russia, as an offensive as distinct from a defensive force, is the creation of the past ten years. In 1893 she possessed only one complete first-class battleship, the *Peter the Great*, of 8749 tons displacement, and this vessel having been built as long ago as 1872, was of doubtful value as a fighting unit. In addition, she owned four armoured ships of from four to six thousand tons each, mere coast defence ironclads, and small at that. This was the whole of her armoured fleet ten years ago, apart from the force immured by solemn treaty obligations within the Black Sea. To-day Russia has three great fleets, and one small one in the Caspian Sea.

Since a comprehension of the naval position of Russia is impossible unless the peculiar political circumstances affecting the Black Sea are understood, it is well that the situation should be explained at the outset; on it hinges Russia's position in European waters. The Black Sea is bounded by the territories of Russia, Roumania, Bulgaria and Turkey. From the fall of Constantinople (1453) until 1774 all vessels, except those of Turkey, were excluded from it. In the latter year Russia was allowed to trade there, and later the Austrians obtained similar rights; but it was not until the Treaty of Amiens in 1802 that the flags of Great Britain and France were admitted. In 1854 the allied fleets entered the Black Sea, the Russian squadron was absolutely destroyed, and by the subsequent Treaty of Paris the sea was closed to ships of war in the hope that thereby Europe might be spared further trouble from that quarter.

In 1871, however, when France and Germany were at war and Great Britain was preoccupied, the Russian Government suddenly declared that it considered itself no longer bound by the Treaty of Paris. At that time Abdul Aziz, to secure his territory, had provided a big fleet, and seven years later, when Russia declared war against the Porte, the Turks were so strong afloat that the Russians had to carry out the invasion of the Sultan's territory by land, at an immense cost and much delay. Russia took this lesson to heart, and it became her policy to keep in the Black Sea a fleet sufficiently powerful to deal with Turkey on any future occasion.

By the arrangement agreed to when the powers conceded to Russia in 1871 the right to keep ships of war in the Black Sea, it was laid down that the Dardanelles should be closed to all ships of war, in other words, that Turkey, with the assistance of the powers if necessary, should bar all men-of-war from



THE AMERICAN-BUILT RUSSIAN CRUISER "VARIAG." DISPLACEMENT, 6500 TONS. SPEED, 23 KNOTS

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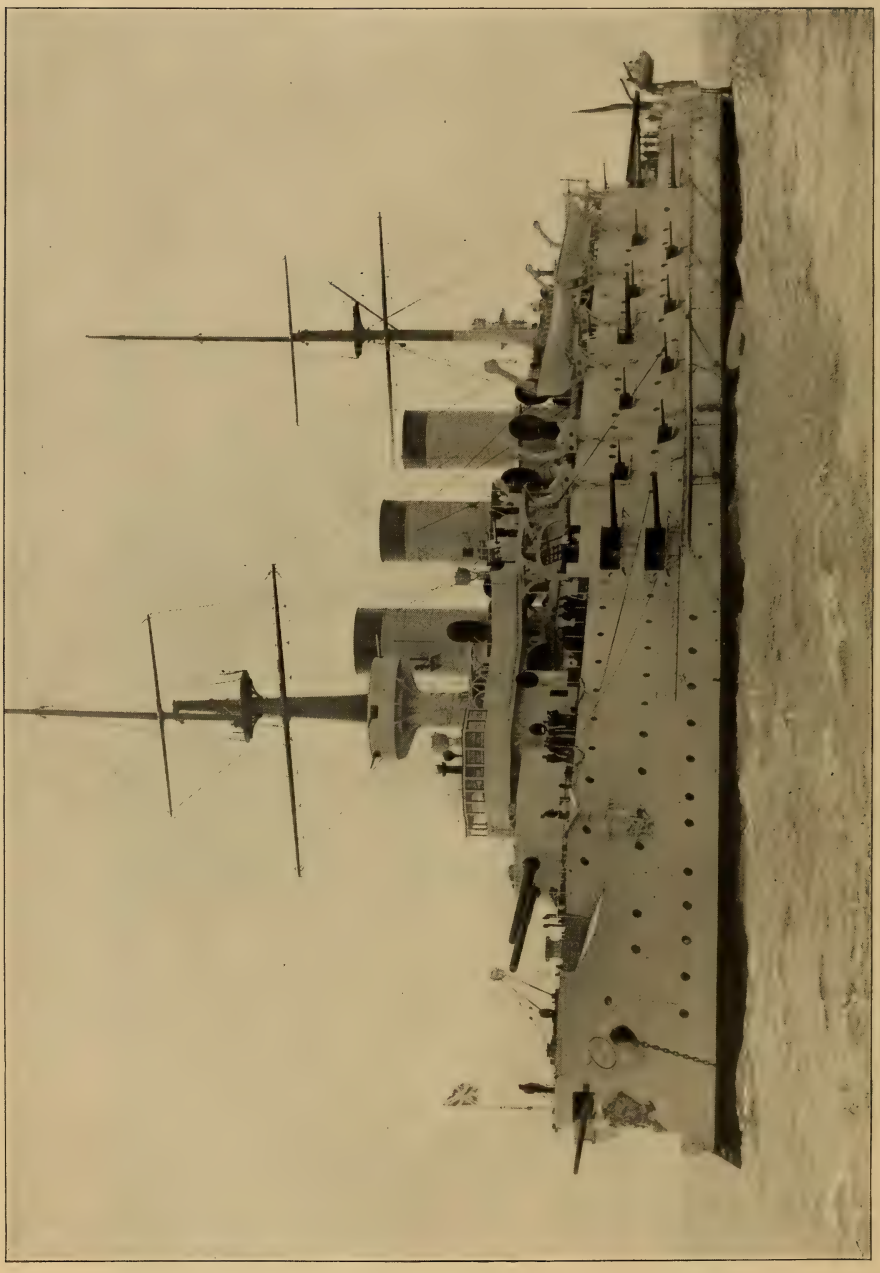

THE BATTLESHIP "POBIEDA" (VICTORY) STANDS HIGHER OUT OF THE WATER THAN ANY OTHER WARSHIP IN THE WORLD AND THUS MAKES A MOST CONSPICUOUS TARGET. DISPLACEMENT, 12,675 TONS

PHOTO BY STEPHEN CRIBB, SOUTHSEA

passing out into the Mediterranean. Since 1856 no man of-war has steamed through the Dardanelles, save on two occasions recently when four Russian torpedo-boats, with, it is said, all armaments removed, passed through. It was assumed that the passage was made to try the pulse of Europe, and it was accepted as a presage of what will happen when Russia thinks the time is opportune to abrogate the last clause in the Treaty of Paris which binds her action as *the* naval power of the Black Sea. Nominally her fleet in the Black Baltic, frozen up during many months of the year; another is in the Black Sea, immured by a treaty which may or may not be worth the paper it was written on; a third, a small force, is in the Caspian; and the fourth, and most important from a political standpoint, as well as the most recent in creation, is in the Far East. Each of these forces is distinct and almost as completely isolated from the rest as though it belonged to a separate country.

Having explained the conditions under which Russia established herself as

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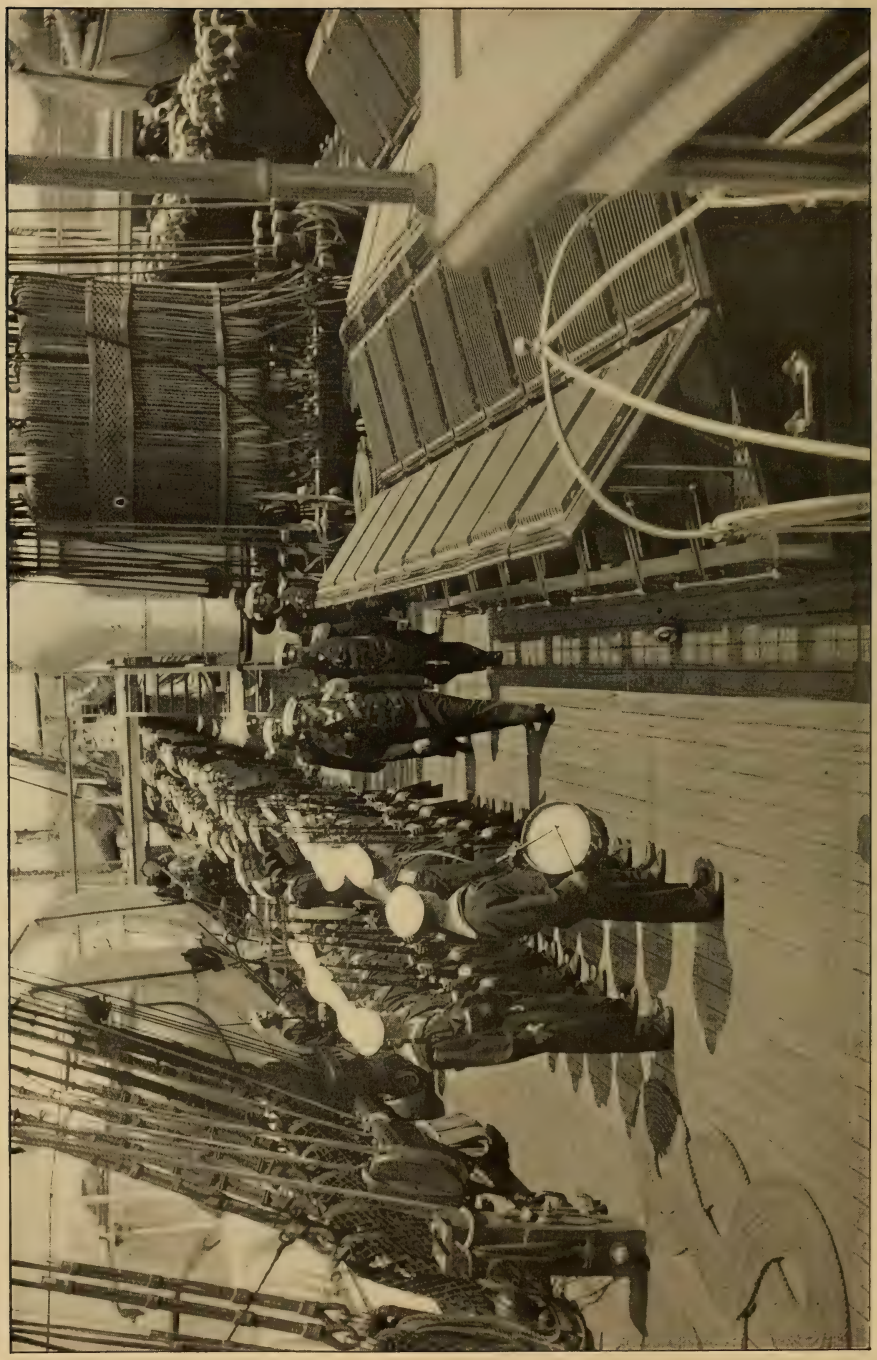
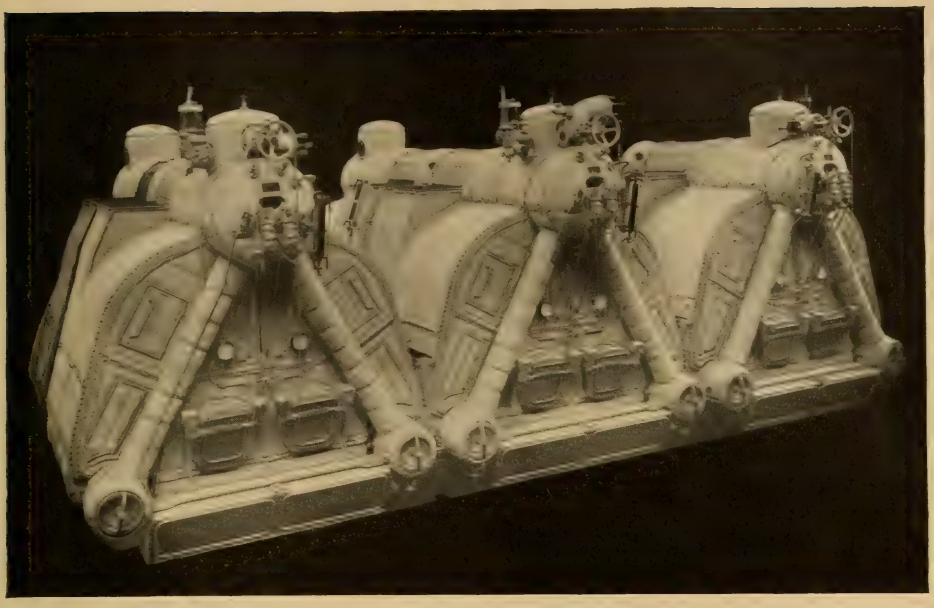
Sea would be useless in case of war in the Mediterranean; as a matter of fact, no one believes that this restriction would be respected.

At the present day Russia ranks as one of the leading naval powers of the world; but, owing to the circumstances already narrated and her geographical situation, she is placed in a position of unique disadvantage. She is compelled to maintain four fleets; one is in the mistress of the Black Sea, it remains to explain how she came to be the dominating factor in the Far East. When Japan had defeated China and had made her terms, Russia, with the support of Germany and France, stepped in between the late combatants and refused to permit Japan to retain Port Arthur, which she had captured by force of arms. This occurred in 1895. In 1898 the Tzar allotted a sum equivalent to



SUNDAY MORNING INSPECTION ON A RUSSIAN CRUISER



SOME OF THE WATER-TUBE BOILERS OF THE CRUISER "BOGATYR." SEE PAGE 318. BUILT AT THE VULCAN WORKS, STETTIN, GERMANY

nine millions sterling, to be expended on new ships, in addition to the amounts to be provided in the ordinary votes in the course of the ensuing six years. A little more than twelve months afterwards Russia obtained a "lease" of Port Arthur and Talienwan, and other powers took chips out of the Chinese Empire. Russia, meantime, sent practically every available ship to the Far East with the double object of protecting her new possessions and the railway rights which she had obtained in Manchuria, and of impressing the Chinese and the world at large. When the Boxer trouble occurred in 1901 she had a commanding fleet in adjacent waters, and her troops overran Manchuria to protect, as it was alleged, her railway. The disturbances being at an end, the other powers withdrew a large proportion of their ships, while Russia, promising to recall her troops from Manchuria at an appointed date, sent out more ships and gradually and quietly accumulated at her two naval bases, Port Arthur and Vladivostock, the formidable fleet,—far larger than that of any other European power,—which is there to-day, and of which so much has been heard in the last few months.

The Russo-Turkish War first directed the attention of the modern rulers of Russia to the importance of a fleet in the Black Sea, and in 1882 the Tzar sanctioned an expenditure of 21,000,000 sterling towards its development. Ten years later the growing activity afloat of her European neighbours led to a further expansion of the programme of shipbuilding, this time with a view to strengthening the forces in the Baltic, and then in 1898 came the scheme for creating a powerful fighting fleet in the Far East, where in the past only a small force had been maintained. Neither want of ready money, nor of trained officers, nor of trained shipbuilders has ever stood in the way of Russia's aspirations when it has been thought desirable to build a new fleet.

To a great extent the Russian Navy was in early days the offspring of the British Navy. It was on the Thames, at Deptford, that Peter the Great watched the process of shipbuilding, and it was from the Thames that he set out later for home with a large body of

TABLE I.

BATTLESHIPS

(8 in Black Sea and 12 Others)

No.	Name	Date of Launch	Displacement. Tons	Armament	Speed. Knots	Full Coal Capacity. Tons	Radius of Action at 10 Knots. Miles
1	† * Rostilav	1895	8,880	4 10-inch 8 6-inch Q. F. 28 smaller guns 4 torpedo-tubes	16	800	2,000
3	Sabastopol Poltava Petropavlovsk	1894–5	10,960	4 12-inch 12 6-inch Q. F. 34 smaller guns 4 torpedo-tubes	17½	1,050	3,400
1	Sissoi Veliki (Sissoi the Great) (Reconstructed 1902)	1894	8,880	4 12-inch 6 6-inch Q. F. 30 smaller guns 6 torpedo-tubes	16	1,200	2,000
1	† * Tri Svyatitelya (Three Saints)	1893	13,318	4 12-inch 8 6-inch Q. F. 4 4-inch Q. F. 52 smaller guns 6 torpedo-tubes	17¾	1,000	3,900
1	* Georgei Pobyedonosets (George the Victorious)	1892	11,940	6 12-inch 7 6-inch 20 smaller guns 7 torpedo tubes	16½	1,000	4,000
1	Navarin	1891	9,476	4 12-inch 8 6-inch 32 smaller guns 6 torpedo-tubes	16	1,200	----
1	* Dvyenadtsat Apostolof (Twelve Apostles)	1890	8,400	4 12-inch 4 6-inch 32 smaller guns 6 torpedo tubes	16½	800	----
3	* Sinop * Catherine II. * Tchesmé	1886–7	10,181 10,048 10,930	6 12-inch 7 6-inch 14 smaller guns 7 torpedo-tubes	16½	870	1,350 (at 14 knots)
2	Imperator Nikolai I. Imperator Alexander II.	1889 1887	9,672 9,244	2 12-inch 4 9-inch 8 6-inch 22 smaller guns 6 torpedo-tubes	16	1,200	1,500 (at 14 knots)
3	† Peresviet † Pobieda (Victory) † Ossliabya	1898	12,674	4 10-inch 11 6-inch Q. F. 50 to 54 smaller guns 5 torpedo-tubes	18 to 19	2,056	----
2	† Retvizan	1900	12,902	4 12-inch 12 6-inch Q. F. 54 to 58 smaller guns 4 torpedo-tubes in Retvison and 6 in Tzarevitch	19	2,000	8,300
	Tzarevitch	1901	13,100		19	1,350	5,500
1	†* Knyaz Potemkin	1900	12,480	4 12-inch 16 6-inch Q. F. 28 smaller guns 5 torpedo-tubes	17	900	3,000

ARMOURED CRUISERS (8)

1	Bayan	1900	7,726	2 8-inch 8 6-inch Q. F. 32 smaller guns 2 torpedo-tubes	22	1,100	3,000 (at 18 knots)
1	Gromoboi	1899	12,364	4 8-inch 16 6-inch Q. F. 60 smaller guns 5 torpedo-tubes	20	2,100	17,500
1	† Rossia	1896	12,200	4 8-inch 16 6-inch 50 smaller guns 5 torpedo-tubes	19½	2,500	19,000
1	Rurik	1892	10,933	4 8-inch 16 6-inch Q. F. 6 4.7-inch Q. F. 14 smaller guns 4 torpedo-tubes	18¾	2,000	19,000
1	Pamyat Azova (Reconstructed 1902)	1888	6,734	2 8-inch 17 6-inch Q. F. 17 smaller guns 3 torpedo-tubes	18	1,000	10,000

TABLE I.—(CONTINUED)

ARMOURED CRUISERS—(*Continued*)

No.	Name	Date of Launch	Displacement. Tons	Armament	Speed. Knots	Full Coal Capacity. Tons	Radius of Action at 10 Knots. Miles
1	Admiral Nakhimoff (Reconstructed 1900)	1885	8,524	8 8-inch 10 6-inch No smaller guns 3 torpedo-tubes	19	1,300	8,000
1	Dmitri Donski	1883	6,200	6 6-inch Q. F. 10 4.7-inch Q. F. 30 smaller guns 5 torpedo-tubes	15½	400	4,800
1	Vladimir Monomoch (Reconstructed 1897–8)	1882	5,593	5 6-inch Q. F. 6 4.7-inch Q. F. 26 smaller guns 3 torpedo tubes	15	400	----
				PROTECTED CRUISERS (13)			
1	Bogatyr	1901	6,645	12 6-inch Q. F. 26 smaller guns 6 torpedo-tubes	24	1,430	----
1	Askold	1900	5,905	12 6-inch 24 smaller guns 6 torpedo-tubes	24½	1,100	----
1	Varyag	1899	6,500	12 6-inch 26 smaller guns 6 torpedo-tubes	23¼	1,250	----
3	Aurora Diana Pallada	1900 1889 1899	6,731 7,081 6,630	8 6-inch 34 smaller guns 3 torpedo-tubes	20	1,430	5,500
1	Svyetlana	1896	3,862	6 6-inch Q. F. 12 smaller guns 2 torpedo-tubes	20¼	400	7,000
1	†Novik	1900	3,000	6 4.7-inch 9 smaller guns 6 torpedo-tubes	26	600	5,000
1	Admiral Kornilov	1887	5,800	14 6-inch 18 smaller guns 6 torpedo-tubes	18	1,100	15,000
1	Boyarin	1901	3,200	6 4.7-inch Q. F. 12 smaller guns 5 torpedo-tubes	23¼	650	5,000
1	Almaz	1900	3,285	6 4.7-inch 11 smaller guns 6 torpedo-tubes	19	500	6,000
1	Rynda	1885	3,508	10 6-inch 13 smaller guns 1 torpedo-tube	15	700	2,400
				ARMOURED COAST-DEFENCE VESSELS (7)			
1	Gen. Admiral Apraxin	1896	4,126	3 10-inch 4 6-inch Q. F. 24 smaller guns 4 torpedo-tubes	16	400	2,500
1	Khrabri	1895	1,735	2 8-inch 1 6-inch Q. F. 13 smaller guns 1 torpedo-tube	15	200	----
2	Admiral Senyavin Admiral Oshakoff	1894 1893	4,126	4 9-inch 4 6-inch Q. F. 26 smaller guns 4 torpedo-tubes	16	400	2,500
3	‡Otvajni ‡Gremyashtchi ‡Grozyashtchi	1892 1892 1890	1,750 to 1,492	1 9-inch 1 6-inch 8 to 15 smaller guns 2 torpedo tubes	15	200	----
6	Old vessels built	1865–8	----	Little or no fighting value	--	----	----
				TORPEDO VESSELS (9)			
9	----------	1889–1896	400–742	6 to 15 small Q. F. guns	--	----	----
				TORPEDO-BOAT DESTROYERS (54)			
				Built and Building			
54	----------	1895–1902	240–350	1 12-pdr Q. F. 3 small Q. F. guns 3 torpedo-tubes	27–30	----	----

THE RUSSIAN ARMOURED TRIPLE-SCREW CRUISER "ROSSIA." LENGTH, 480 FEET. BREADTH, 68 FEET. DISPLACEMENT, 12,130 TONS

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TABLE I.—(CONTINUED)

TORPEDO BOATS (169)

No.	Name	Date of Launch	Displacement. Tons	Armament	Speed. Knots	Full Coal Capacity. Tons	Radius of Action at 10 Knots. Miles
No.	Name	Date of Launch	Displacement		Armament		
87	First-class	1889-1900	80-215		Various		
82	Second-class	--------	------		--------		

SUBMARINE BOATS (2)

		Building					
2	----------	1901	------		--------		

* Black Sea Squadron. † These ships are fitted to carry liquid fuel. ‡ These vessels are only gunboats.

workmen skilled in the use of tools to assist him in the upbuilding of a fleet to hold Sweden in check. How strange such an aim sounds to-day. In later times many British naval officers, Admirals Elphinstone, Greig, and a score of others, were tempted into the Russian service, and until recent years not a few of the ships of the Russian Navy were constructed in British yards, of British material, and with British labour.

With splendid determination the Muscovite power has now thrown off outside assistance, and, despite all difficulties, has developed her resources. At St. Petersburg she has to-day six big building slips, so that six battleships or large cruisers may be in progress at one and the same time; Cronstadt is mainly a repairing yard; the Baltic yard, at the mouth of the Neva, has been much improved and provided with a new building slip since it came into the hands of the government a few years ago; and Libau is the new advanced base of the Russian Navy at a point in the Baltic which is not frozen up each winter. At Sebastopol and Nicolaieff, in the Black Sea, there are good building and docking facilities, and since Vladivostock was adopted as the Far Eastern base a splendid new dock, 550 feet long and 90 feet wide, has been constructed and another dock is in hand, and steps are being taken to fit Port Arthur as a strongly defended naval base. This harbour already has one dock, with smithy and shop. The fixed defences at Port Arthur have been practically completed, and work on a new dock is already in hand.

Not many years ago Russia had to turn to other powers for almost everything she required for the construction of her ships; but she has now rendered herself to a great extent independent of outside assistance by the provision of steel, gun and armour works. Even her engines, which ten years since she was obtaining largely from such British firms as Humphrys, Tennant & Co., of Greenwich; Hawthorn, Leslie & Co., Ltd., of Newcastle-on-Tyne, and Maudslay, Sons & Field, of London, she is able to produce in an increasing degree herself, either at the Russo-Belgian Company's works at Nicolaieff, or at the Baltic Engineering Works. In the Russian ships, use is made of Thornycroft, Yarrow, Belleville and Shultz boilers, while a portion of the armament is obtained from Krupp, of Essen, Germany, and from Canet, in France.

Bearing in view the rapid extension of the Russian Navy in the past ten years, and the aid given by American and French and German and, to a small extent, British shipbuilders and engineers, it is astonishing to note the strides of Russia in the development of her own resources, so that to-day she is able to boast that, in carrying out the programme of shipbuilding lately adopted, she will not need to go to foreign countries for any of the vessels, as she had to do as recently as 1898, when her need for men-of-war for dealing with the fast developing situation in the Far East was so urgent that she could not wait to permit all the work to be done within the Empire.

The present is a convenient opportunity for considering the fighting strength of the Russian fleets, because the list of ships comprised in the programme of 1898 has been practically

THE BATTLESHIP "RETVIZAN." DISPLACEMENT, 13,000 TONS

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completed, and the Tzar's Government has lately issued orders which indicate that it is to be succeeded by another ambitious effort towards further expansion. There is a slight gap between the old and the new designs, and this gives an excuse for an examination of the policy which has been behind the plans of the Russian Admiralty, the number of the ships and their character.

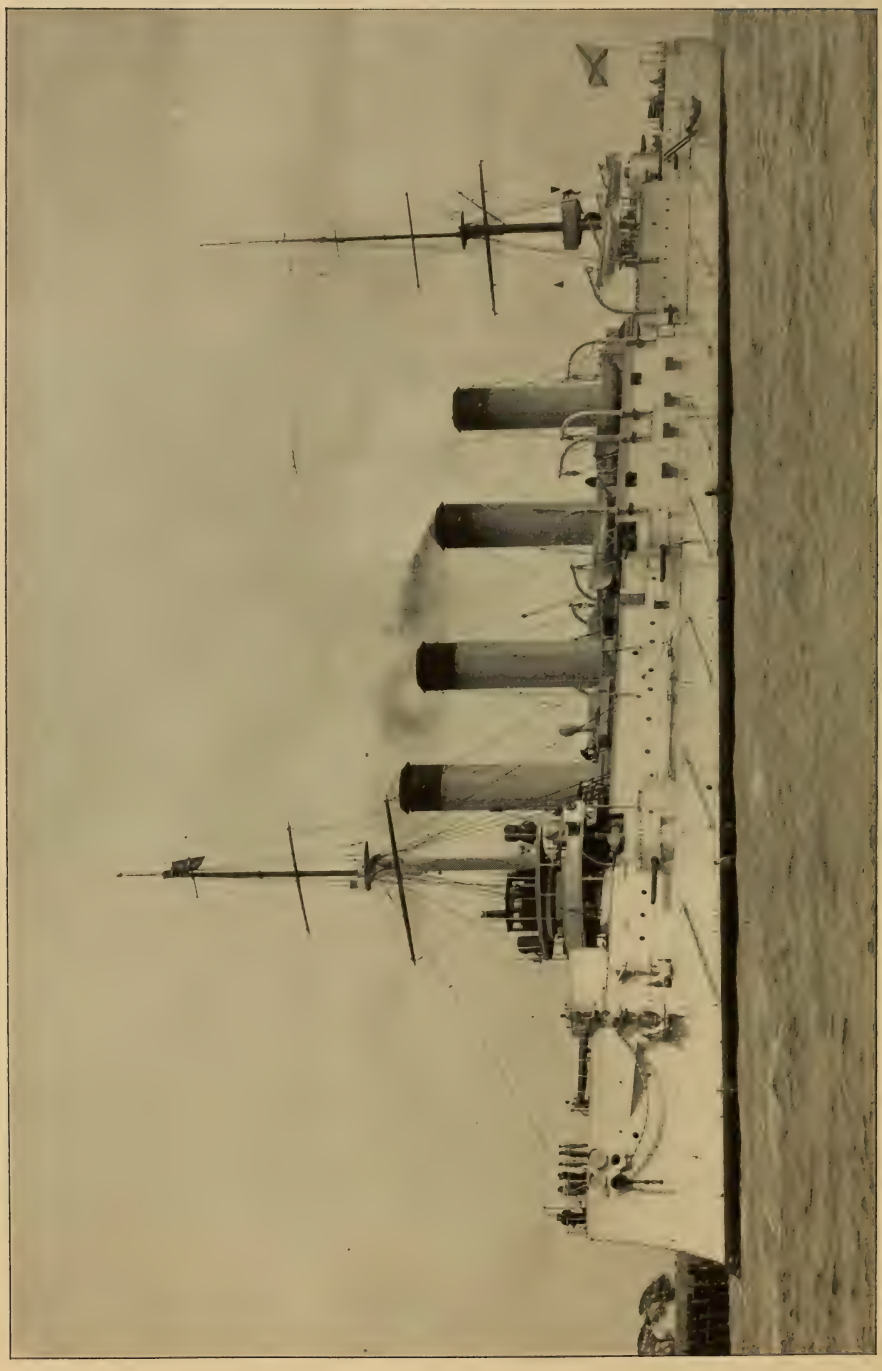
Russia has set herself the task of providing three powerful fighting fleets, each with its proportion of battleships of heavy armament, good defensive qualities, and good radius of action, for her three main spheres of action, the Baltic, the Black Sea, and the Far East, the last being recognised as of first importance. Secondly, she has equipped herself with a large number of armoured and heavily protected cruisers, for one of the planks in the programme to which importance is attached is the destruction of an enemy's sea-commerce. On these lines the fleets have been built up, and now that the Far Eastern squadron has been made a force so strong that it compels respect from all the nations which have gathered round China, attention is being turned, in some degree, to the needs of the Baltic, where Germany is becoming a menace, and to the Black Sea, where Turkey is showing signs of greater decrepitude and Roumania is busily raising a strong, though purely defensive force.

Some idea of the size and strength of the Russian Navy at present, including ships completed, or practically completed, may be had by reference to Table I., on pages 308, 309, and 311.

Russia also possesses a number of old, unprotected cruisers, of which account need not be taken, since they are of practically no value.

THE CRUISER "ASKOLD." DISPLACEMENT, 6100 TONS. SPEED, 24 KNOTS. BUILT AT THE FRIED. KRUPP GERMANIAWERFT, KIEL, GERMANY. THE ONLY FIVE-FUNNEL WAR SHIP IN EXISTENCE

Even if the ships belonging to the Black Sea fleet are eliminated, it must be evident that Russia has made much progress in the past ten years. Her navy, in spite of the disadvantages under which it labours, is far from being a negligible quantity. She has built up a force which well merits examination and study, not only for what it is to-day, but for what it promises to be in the near future. The programme of 1898 having been virtually completed, Russia has now set her hand to a far more ambitious project than any which she has hitherto attempted. In her new ships she has answered what in Russia was considered the British and



THE ARMOURED CRUISER "BAYAM." DISPLACEMENT, 7800 TONS. SPEED, 21 KNOTS

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American challenge, embodied in the decision to construct ships each of 16,000 tons displacement. When the British and American plans were announced, the conclusion was that the abnormal size represented by such a displacement would mark finality, since such mastodons could be built only by powers with ample financial resources. In a few years, it was asserted, Great Britain and the United States would have battleships so powerful in offence and defence, so amply provided with stores of all kinds, coal and ammunition, that they would has begun the construction of a squadron of four of these men-of-war of gigantic size, with one in reserve, which is the plan that commends itself most to the naval authorities. In addition to the five Russian ships, some of which are, of course, destined for the Far East, two battleships for the Black Sea, each displacing 12,500 tons, are being built. This measure is not called for, so far as can be observed by any steps taken by Turkey or other power, and will be accepted as evidence that in building nominally for this enclosed water, Russia

TABLE II

BATTLESHIPS (12)

No.	Name	Date of Launch	Displacement. Tons	Armament	Speed. Knots	Full Coal Capacity. Tons	Radius of Action at 10 Knots. Miles
5	Boradino Imp. Alexander III. Oral Kniaz Suvoroff Slava	1901 1901 1902 1902 1903	13,516	4 12-inch 12 6-inch Q. F. 48 smaller guns 6 torpedo-tubes	18	12,500	8,500
2	*Zlatoust *Evstafi	----	13,000	4 12-inch 16 6-inch guns smaller guns	18	----	----
5	Andrei Pervozvannui Imperator Paul Three unnamed, projected	----	16,500	4 12-inch 12 8-inch smaller guns 4 torpedo-tubes	18	3,000	----
	ARMOURED CRUISERS (2)						
2	Unnamed, projected	----	7,000	Will probably resemble the Bayan	18	----	----
	PROTECTED CRUISERS (5)						
2	Jemtchug Izumrud	----	3,000	6 4.7-inch Q. F. 10 smaller guns 5 torpedo-tubes	25	650	5,000
3	*Kagul *Otchakow Oleg	----	6,645	12 6-inch 26 smaller guns 6 torpedo-tubes	23	1,430	----

* Black Sea Squadron.

be practically invulnerable under the attack of the smaller battleships of other nations; outside the Anglo Saxon family, it was said, there is no nation with resources which would admit of such huge and expensive ships being built. These anticipations have been already falsified. Russia has issued her reply. Content ten years ago with vessels of most moderate dimensions, she is now determined to vie with the two richest nations in her naval equipment.

The new programme of the Tzar's Government includes no fewer than five battleships of 16,500 tons. Russia realises that her rivals may send some of their monster ships to the Far East and thus jeopardise her position, so she is really cherishing the hope that her ships may yet play a part in a struggle in the Mediterranean. Two large cruisers are also about to be laid down, but these are for the Far East and not for the Baltic.

As an illustration, in brief, of the progress of Russia's naval ambitions, it will be interesting to append a statement, Table II., of the large ships now under construction, from which it will be seen that in a few years the Russian fleets at sea will receive important accessions of strength.

This must be accounted an ambitious programme for a power which, ten years ago, had only one completed battleship outside the Black Sea. In particular

the decision to lay down five leviathan battleships of 16,500 tons is a most significant departure. It is an indication that however much France, her ally, may slacken her pace in the contest for sea power, Russia at least is not content to leave the struggle for the command of the sea in the Pacific to either Great Britain, the United States or Japan. The adoption of the 16,500-ton design may be accepted by politicians as an indication that Russia regards her position in Manchuria as now assured against all interference, and when the time arrives, when the new ships, or some of them, are on her Pacific station, assuredly she

TABLE III.

No.	Country	Displacement	Armament
5	Russia	16,500	4 12-inch 12 8-inch 20 3-inch Q. F. 4 torpedo-tubes
5	Great Britain	16,350	4 12-inch 4 9.2 inch 10 6-inch Q. F. 28 smaller guns 4 torpedo-tubes
3	United States	16,000	4 12-inch 8 8-inch 12 7-inch Q. F. 20 3-inch Q. F. 28 smaller guns No torpedo-tubes
5	Germany	13,208	4 11-inch 14 6.7-inch Q. F. 24 smaller 6 torpedo-tubes
6	France	14,692	4 12-inch 18 6.4 inch Q. F. 28 smaller guns 5 torpedo-tubes
5	Italy	12,624	2 12-inch 12 8-inch Q. F. 12 4-inch Q. F. 12 smaller guns 4 torpedo-tubes

will openly annex Manchuria, relying upon her naval power to obtain the acquiescence of the other powers.

The decision of Great Britain, the United States, and Russia to construct ships of 16,000 tons displacement is an amazing one, and may have an important influence on the balance of naval power in the world. If these ships are worth the heavy outlay they entail, approximately one million and a quarter sterling each, they will be far and away superior to such vessels as France, Germany and Italy are continuing to build. If they are not, they stand condemned. There is every reason to believe, however, that these vessels will be so well armoured and armed that they will be able to overbear, by sheer weight of discharge and impregnable defence, the efforts of smaller ships. The position of the great powers with reference to the construction of big battleships is indicated, in summary, in Table III., which indicates the divergence which is showing itself between the old-time first-class naval powers and the countries which are outstripping them, for the simple reason that America and Great Britain have the longest purses, while Russia realises that her diplomatic position in the Far East depends on her ability to maintain her position in spite of Anglo Saxon armaments. The largest ships for each of the powers are given in Table III.

Details are still wanting to enable a complete comparison of the armour protection which these vessels will possess.

Two classes of Russian cruisers are specially interesting, the type represented by the *Askold*, the *Variag*, and the *Bogatyr* on the one hand, and the smaller ships, of which the *Novik* is the parent. In some respects these men-of-war are not surpassed in any other navy, and in particular their speeds are extraordinary. The *Askold* and her sisters are improvements upon the *Aurora*, *Diana*, and *Pallada*, but are much swifter. When Russia decided to improve her type of second-class cruiser in 1898, she sought to avail herself of the designs submitted by a number of firms, —Messrs. Cramp, Krupp, and Schichau, and the Vulcan Company notably. The Vulcan Company succeeded best in pleasing the Russian authorities, and consequently four sisters of the *Bogatyr* will be built. The designs of these cruisers are of sufficient interest to justify a skeleton comparison.

	Askold	*Variag*	*Bogatyr*
Builder	Krupp	Cramp	Vulcan Co.
Length	426½ ft.	420 ft.	416¾ ft.
Beam	49 ft.	52 ft.	54½ ft.
Mean draught	20¼ ft.	20 ft.	26¾ ft.
Displacement	6,100	6,500	6,750
*Armament—Twelve 6 in., twelve 3-in., eight 3-pounders, and two 1-pounders.			
*The *Variag* has only six 3-pounders and no 1-pounders. She has only two torpedo tubes above water and two submerged			
ARMOUR—			
Deck, slopes	3 in.	3 in.	2.75 in.
Turrets, one forward and one aft.	nil	nil	3½-5 in
Casemates, four	4 in.	nil	4 in.

THE CRUISER "BOGATYR." DISPLACEMENT, 6750 TONS, SPEED, 23 KNOTS. BUILT AT THE VULCAN WORKS, STETTIN, GERMANY

Conning tower	6 in.	6 in.	6 in.
Hoists	1½ in.	1½ in.	2 in.
Funnel bases	1½ in. slop'g	nil	2 in. vert.
Boilers	Schulz-Thornycroft	Ni-clausse	Normand Express
Speed	24.5 k'ts (for 6 hrs.)	24.6 k'ts (for 8 hrs.)	23.45 k'ts (for 8 hrs.)
Screws	3 (3 sets of trip. exp. engines)	2	2
Coal, normal and max. (tons)	720-1,100	770-1,250	720-900

No one will gainsay that on such a moderate displacement there are very fine results. The ships are all well-armed and well-protected, and they are among the swiftest ships in the world's navies. An incident illustrating the quickness with which the *Askold*, with the Schulz-Thornycroft boilers, can get up steam was narrated at the time of her trials in the *Marine Rundschau*, of June, 1902. Owing to fog, the order for the ship to proceed to sea was countermanded. Later in the day the weather cleared, and she was directed to carry out the original programme. At the moment only one of her nine boilers was in use. Within two hours the *Askold* was not only at sea, but making a speed of 24.5 knots, a performance which has seldom, if ever, been equalled, and which serves to illustrate the military qualities of this British type of boiler.

The other type of Russian cruiser which merits attention is much smaller than those dealt with above, having a displacement of 3000 tons. The *Novik* has been described as a "destroyer-destroyer," and in view of her great speed, which she can better maintain in a seaway than a destroyer can, her protection from small gunfire, and her armament, the description is not inapt. Among men-of-war she is something of a marvel, and is far superior to any of the third-class cruisers of the British fleet. Her main features can best be seen from the following tabulated statement comparing her with the British repliea, the largest of the *Scout* type, the *Sentinel*:—

	Novik	*Sentinel*
Displacement	3,000 tons	2,900 tons
Speed	26 (on trial)	25 (anticipated)
Armament	6-4.7 in. 1 9-pdr. 8 3-pdrs. 2 smaller	10 12-pdrs. (3 in.) 8 smaller
Protection—		
Deck	¾-2 in.	2 in.
Conning tower	1¼ in.	

It would be idle to pretend that the British boat is the better craft, in face of these brief details, as a fighting machine, and the *Novik* has the advantage in coal endurance, since she can carry 650 tons, sufficient for 5000 miles at 10 knots, while the *Sentinel* will have only 380 tons, equivalent to 3000 miles at the same speed. It must be borne in mind that the rate of steaming of the

Russian ship has been actually obtained and is not a "paper" record.

The Russian Navy has always been in the van of mechanical progress, and her ships reflect the latest devices of the inventor. In the matter of screws, however, some inconsistency is revealed, for while she adopted the triple-screw system in the *Tzarevitch*, *Peresviet*, *Oslabia*, and *Podieda*, and also in the *Rossia*, the *Askold* and the *Pallada* class, she has abandoned it in later ships. Again in the matter of funnels, she has been in a great hurry to go one better than other powers, and in the *Askold*, with five funnels, she has a ship with more of these cumbersome objects than any vessel in the navies of the world, excepting only the six-funneled *Jeanne d'Arc*, of France. The truth probably is, not that the number of funnels could not have been kept down, but that they impress Asiatics, who are apt to judge the value of a man-of-war from the number of chimneys they see silhouetted against the sky as the vessel comes over the horizon.

Russian designers have not been slow to realise that the oil fields of their country represent naval power, and many of their large ships, which are the great coal eaters, are fitted to burn liquid fuel. Another feature of several of the Russian ships is that, in the desire to obtain a high angle of fire, the designers have produced vessels which are so much out of the water as to form excellent targets. The battleship *Pobieda* and her two sisters are extreme instances of this careless disregard of a danger which has operated in other navies to check the building of the vessels too far out of the water. The *Pobieda*, *Peresviet*, and *Oslabia* are piled up high above the water-line in most impressive style; but how will all this great area of unarmoured sides fare in warfare, and how will it serve to arrest shells which might otherwise pass over the ships into the water without doing any injury?

So much for the ships of the Russian Navy. What shall be said of the personnel? An officer admitted to the writer, when visiting on board a Russian battleship recently, that a large proportion of the men are not sailors, but agricultural labourers drawn from inland districts by the conscriptive system. They enter as young men,—not, be it noted, as boys,—and serve from five to seven years, and are then passed into the reserve for a further period of eight to ten years. From the fact that these men come from inland provinces, it follows that they have not the love of the sea in their veins, and from the fact that Russia is not an industrial nation, it also follows that few of these men have any mechanical knowledge. Consequently, the navy is manned with the roughest material, men who have to learn everything and unlearn a great deal. It is said that the standard of gunnery is good; but as no records of any kind are published and the ships in Europe are in full commission for only about half the year, and most of the ships in the Far East have been commissioned comparatively recently, such assurances must be received with reservations. No doubt the men possess a high standard of courage, and iron nerves; but these qualities in modern naval war cannot take the place of continuous war training, winter and summer, which is the programme of the British and American and German fleets.

Russia has the ships, she is building more of them, and she has a personnel of 65,054, including many well-trained officers of good attainments; but what the fleet really represents in naval power is a problem which only war can solve. It may be that it will be found, as seems probable, that while the Russian authorities have been able to add to the size of the fleet with marvellous rapidity, they have been unable to supply these ships with adequate complements of trained men. In these days, especially where the aid of foreign yards is invoked, it is possible to obtain ships at short notice; but trained officers and men cannot be so quickly supplied.

Under the circumstances in which the Russian fleet has been created there is consequently good cause to wonder whether it will prove in action as formidable as it appears on paper.

PORTABLE ELECTRIC DRILLING AND RIVETING MACHINES

By Frank C. Perkins

ELECTRICALLY – OPERATED drilling and riveting machines have been used for a number of years in the leading shipyards with great economy and satisfaction. The three types of drills and riveters commonly employed include those operated by electric motors without electro-magnetic devices for holding drills to plates; electro-magnetic drills which are supplied with power by electric motors and are provided with electro-magnets whose office is to hold the drilling machine fast to the plates, and the electro-pneumatic drill or riveter which utilises electricity only to hold the machine against the plate to be riveted, the power for operating the riveter or calker being compressed air, which gives a most powerful stroke and works to good advantage in combination with the electro-magnetic holder-up.

In accompanying illustrations Figs. 2 and 3 show several forms of electric hand drills of German design for use in ship-yards, having been constructed at Stuttgart by the Elektrotechnische Fabrik, C. & E. Fein. These hand drills, it will be noted, are working on the plates of the steamship both from within and from without. Those drills designed to bore holes up to about 1¼ inch in diameter are supplied with a ¼ horse-power motor and consume 300 watts of electric energy, while the smaller drills, designed to bore holes up to only half an inch in diameter, have 1-16 horse-power motors and consume only about 95 watts.

The large drills mentioned above weigh about fifty pounds, while the smaller ones weigh only about twenty pounds, the spindles of the larger machines when driven by direct-current motors having a speed of about 65 revolutions per minute, and when operated by three-phase, alternating-current motors a speed of 68 revolutions per minute. The speed of the direct-current motor is 1300 revolutions per minute,

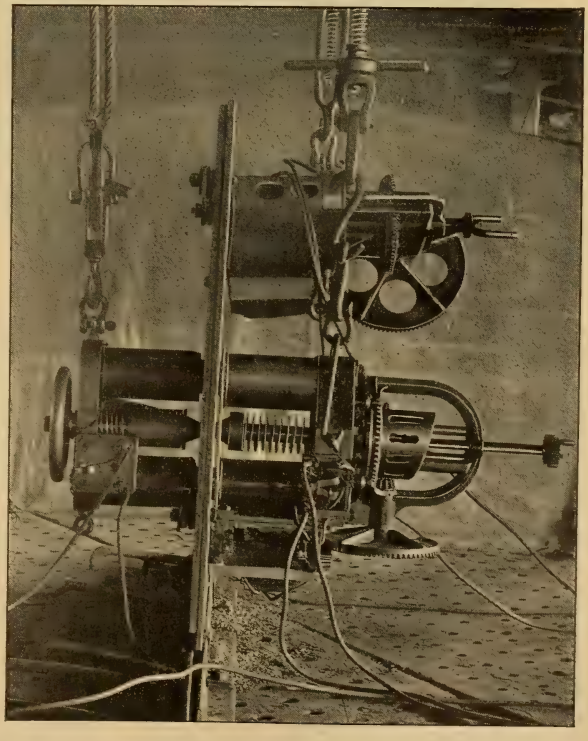


FIG. 1.—ELECTRO-MAGNETIC RIVETER AND HOLDER-UP, MADE BY F. J. ROWAN, GLASGOW

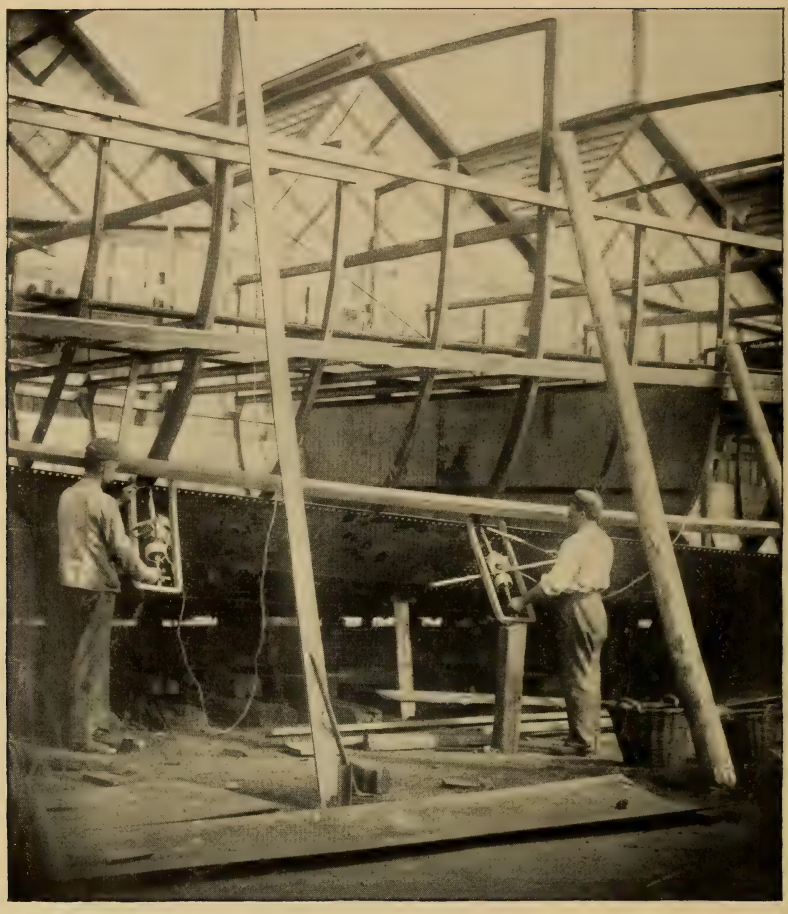


FIG. 2.—SOME GERMAN PORTABLE ELECTRIC DRILLS

and that of the alternating-current motor, 1400 revolutions per minute, the voltages of the former being 65, 110, 220, and 500 volts from power circuits, while the pressure on the three-phase lines may be 110, 190 or 220 volts.

British tools of the kind shown in some of the illustrations in these pages have been employed extensively in the large shipbuilding and engineering works in the United Kingdom and in the arsenals and dockyards of Great Britain, France, Italy, and Russia. One of the most interesting electrical installations in the world using electric power for both stationary and portable machine tools is that of the Société Anonyme des Forges et Chantiers de la Mediterranée at La Seine, near Toulon. This company used electric drilling machines first in the construction of the ships *Matsushima* and *Itsuskushima* for the Japanese Navy, and also in the construction of the first-class French armoured cruiser *Jaurreguiberry*. The machines are said to have drilled nearly a quarter of a million holes in the decks and sides of the first of these ships. It is also stated that, although the machines were designed only for holes up to 1 inch in diameter, the engineers at La Seine worked them on holes 6 inches deep and 1⅛-inch in diameter, in the sternpost of one of the Japanese cruisers, the holes being accurate and smooth without tearing the metal.

FIG. 3.—ANOTHER VIEW. MADE BY THE C. & E. FEIN ELEKTROTECHNISCHE FABRIK, STUTTGART, GERMANY

The electric drill shown in Fig. 4 is of the electro-magnetic type, the pair of magnets noted below being utilised for holding the tool in firm contact with the metal plates to be drilled. The Rowan electro-magnetic riveter and holder-up, shown in position on some iron plates in Fig. 1, was so placed in order that both sides of the riveting apparatus may be seen. In this riveter the hammer is lifted against a spiral spring by means of a helical cam. This cam is turned by an electric motor working through gearing; but while the tool is employed with success for iron rivets, it was found difficult to obtain the requisite force of blows for closing steel rivets by this arrangement, and the blows delivered by the hammer were necessarily given only in one direction, which is at right angles to the surface of the plates. These disadvantages curtail the usefulness of the tool, as the rivets sometimes project through the plates at an angle, frequently on account of the punched holes not being exactly opposite one another. The electro-pneumatic riveter noted in Fig. 7, however, overcomes this difficulty, as it is fitted with a sliding flange, and ball and socket adjustment for altering the direction of the blows on the rivet.

It is often found desirable to have means for electrically drilling holes close to bulkheads, or in angular position, either vertically or horizontally, and a

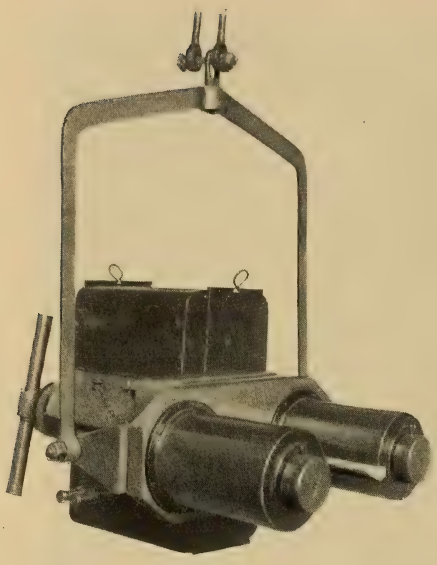


FIG. 4.—AN ELECTRO-MAGNETIC DRILL. THE HOLD ING-ON MAGNET POLES ARE CLEARLY SHOWN WITH THE DRILL BETWEEN THEM

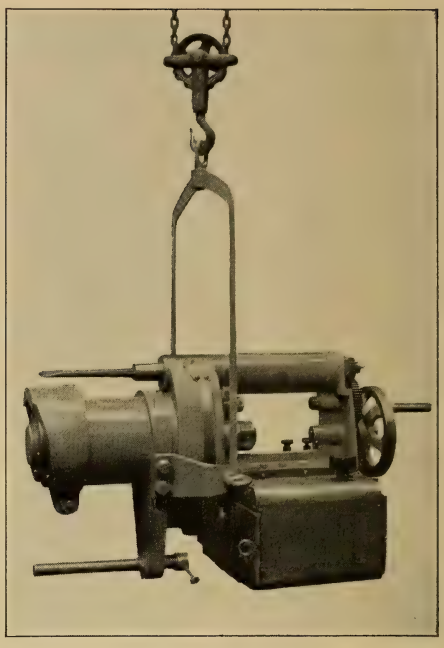


FIG. 5.—AN ELECTRO-MAGNETIC MACHINE FOR WORKING IN CORNERS AND CLOSE TO BULKHEADS

special tubular form of electro-magnet was designed by Mr. F. J. Rowan, of Glasgow, for this purpose. This is shown in Fig. 5. Another form of electric drill is mounted on wheels for moving about on the decks of ships.

Among other interesting electric machines devised at Glasgow by Rowan might be mentioned those for paring off the surplus metal of the rivets in countersunk work, and for finishing snap heads, or the top of countersunk rivet heads by burnishing, so that only a

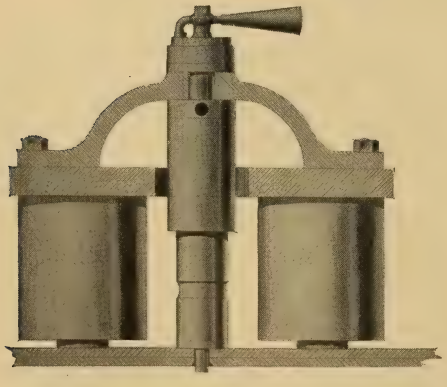


FIG. 6.—AN ELECTRO-PNEUMATIC HOLDER-UP FOR RIVETING. THE ELECTRO-MAGNET IS FOR HOLDING ON THE PNEUMATIC JACK

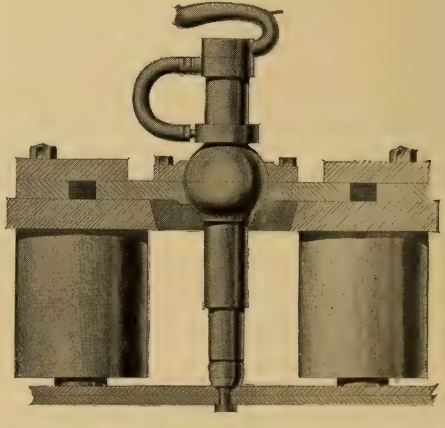


FIG. 7.—AN ELECTRO-PNEUMATIC RIVETER WITH BALL AND SOCKET AND SLIDING ATTACHMENT FOR STRIKING AT AN ANGLE

ALL THE TOOLS SHOWN ON THIS PAGE ARE MADE BY F. J. ROWAN, GLASGOW

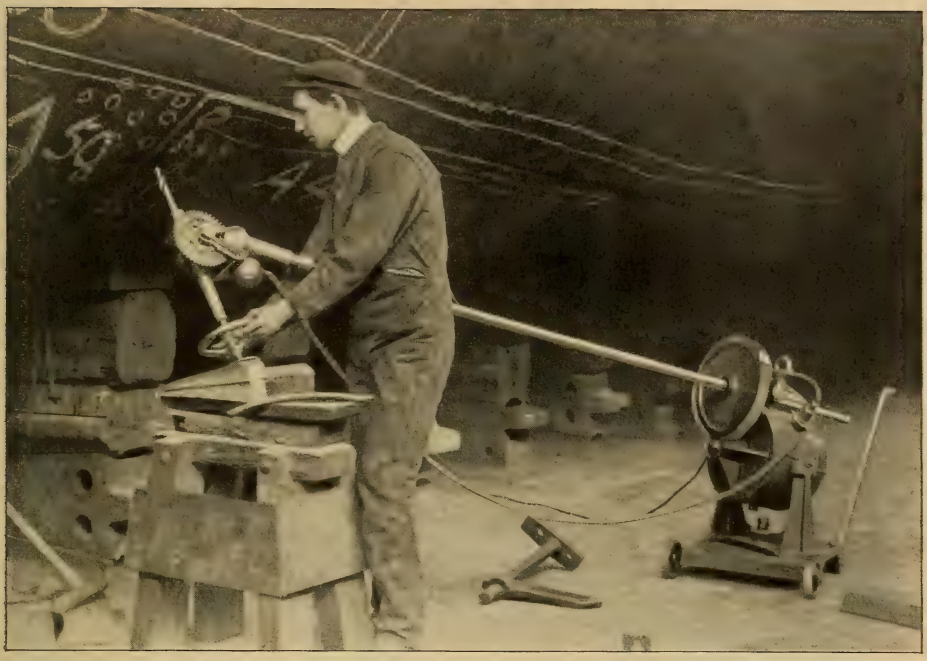


FIG. 8.—AN ELECTRIC DRILLING MACHINE MADE BY MESSRS. CAMPBELL & ISHERWOOD, LIVERPOOL

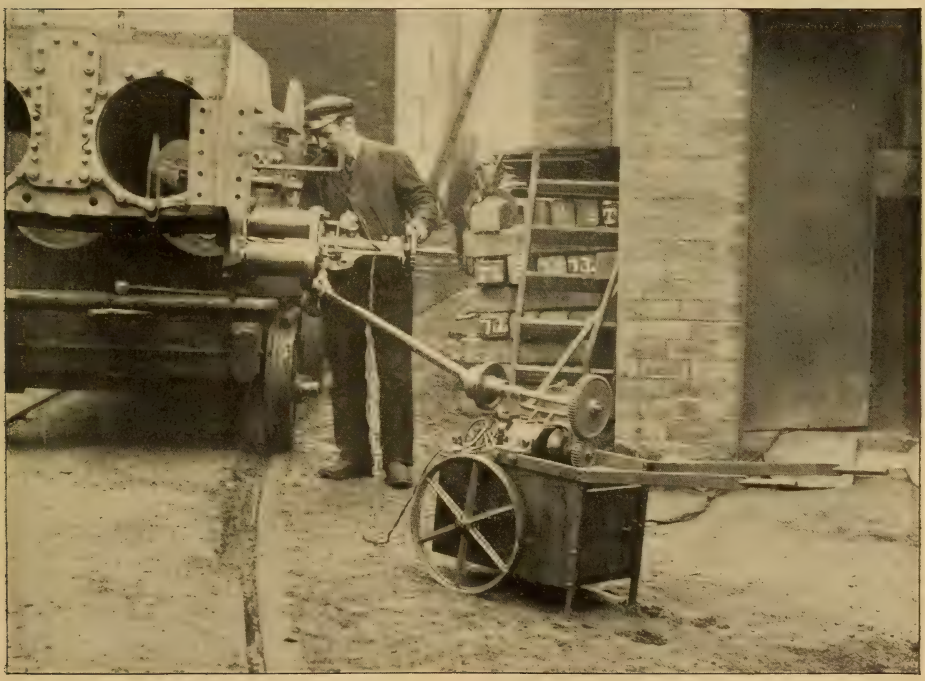


FIG. 9.—A ROWAN ELECTRO-MAGNETIC DRILLING MACHINE WITH DETACHED MOTOR, TELESCOPIC SHAFT, AND MAGNETIC HOLDER-ON

FIG. 10.—A SUSPENDED DRILL WORKING ON SHIP PLATES, MADE BY MESSRS. CAMPBELL & ISHERWOOD, LIVERPOOL, ENGLAND, FOR WHOM THE UNITED STATES METALLIC PACKING CO., LTD., BRADFORD, YORKS., ENGLAND, ARE THE SELLING AGENTS

minimum of hand labour is necessary. Some of Rowan's drills have been used with great economy at Portsmouth Dockyard to drill bolt holes in the steel side-plates of H. M. S. *Royal Sovereign*. These holes extended to a depth of two superposed plates each ¾ of an inch thick, and they were 1 3-16 inch in diameter. Mr. Rowan stated, in a paper on "The Application of Electricity to Engineering Tools," before the Institution of Engineers and Shipbuilders in Scotland, that sixteen holes of these dimensions were drilled by one machine with one man in two hours, including the time spent in moving the drill from point to point. Two picked hand drillers, working on the opposite side of the ship, together drilled fourteen holes by working at twice their usual "piecework" rate, so that the machine did the work of four hand drillers at piecework speed.

Electro-magnetic machine tools can be utilised on board the larger steamships as well as warships, which are now always equipped with electrical installations of ample capacity, and many repairs may easily be done during the voyage which would otherwise have to be done laboriously by hand and take considerable time.

A most interesting form of portable electric drill is that of Messrs. Campbell & Isherwood, of Bootle, near Liverpool. Figs. 8, 10 and 12 show these portable drills in practical operation, one mounted upon a truck, so as to be easily moved about, while the other is unmounted, and arranged for being raised in the air, and utilised for drilling without the use of stay-ropes, steadying gear, or platform. With this particular type of machine, there are no flexible or telescopic shafts, or knuckle joints for transmitting the power from the motor to the drill. The drive is practically direct. It is possible to start and stop the drill instantly without removing the hand from the drill-head, and the whole machine can be easily managed by one man. These drills are extensively used by steamships having an electrical equipment, the engineers having thus at com-

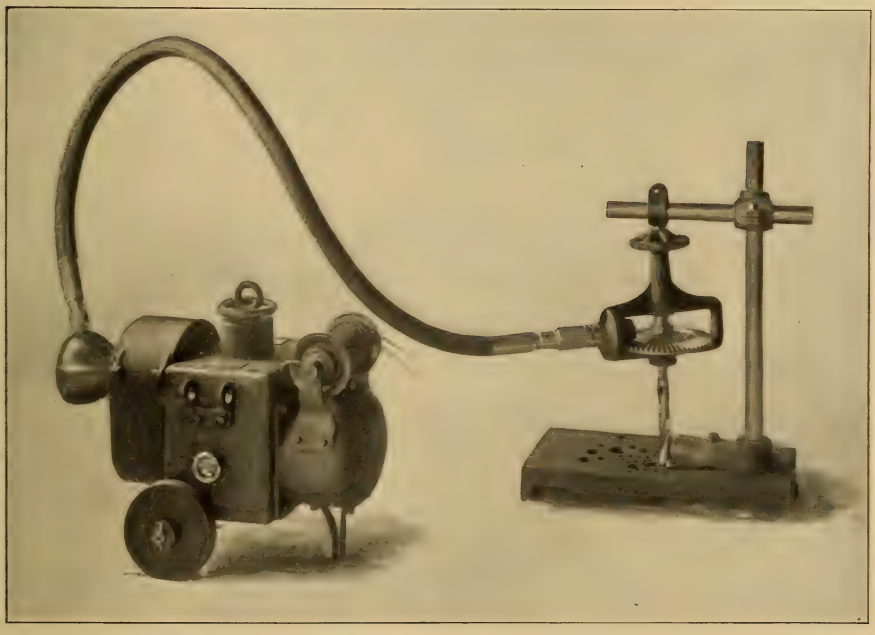


FIG. 11.—A PORTABLE ELECTRIC DRILLING MACHINE WITH A FLEXIBLE SHAFT CONNECTING THE DRILL WITH THE MOTOR. MADE BY THE STOW MFG. CO., BINGHAMTON, NEW YORK, U. S. A.

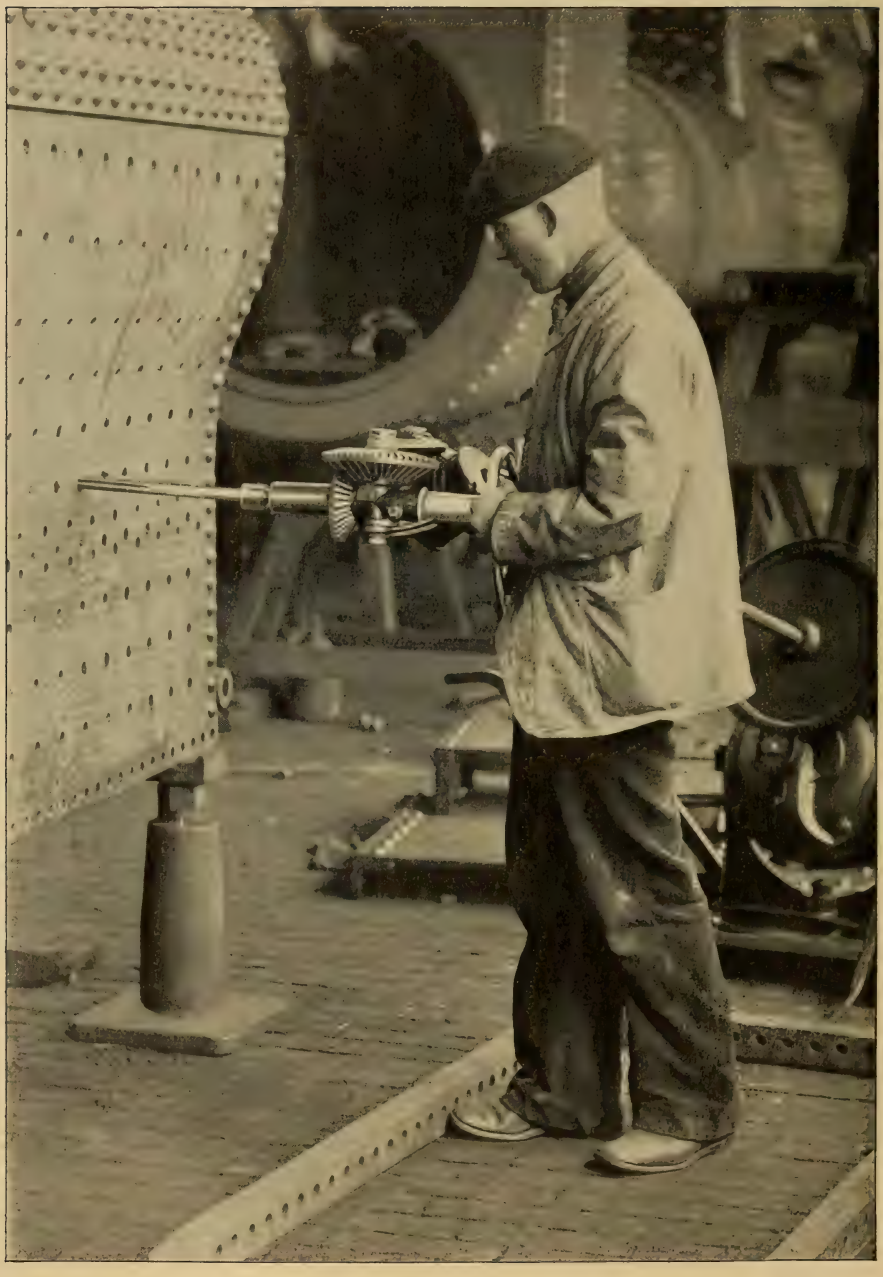


FIG. 12.—BOILER WORK WITH A PORTABLE ELECTRIC DRILL MADE BY MESSRS. CAMPBELL & ISHERWOOD

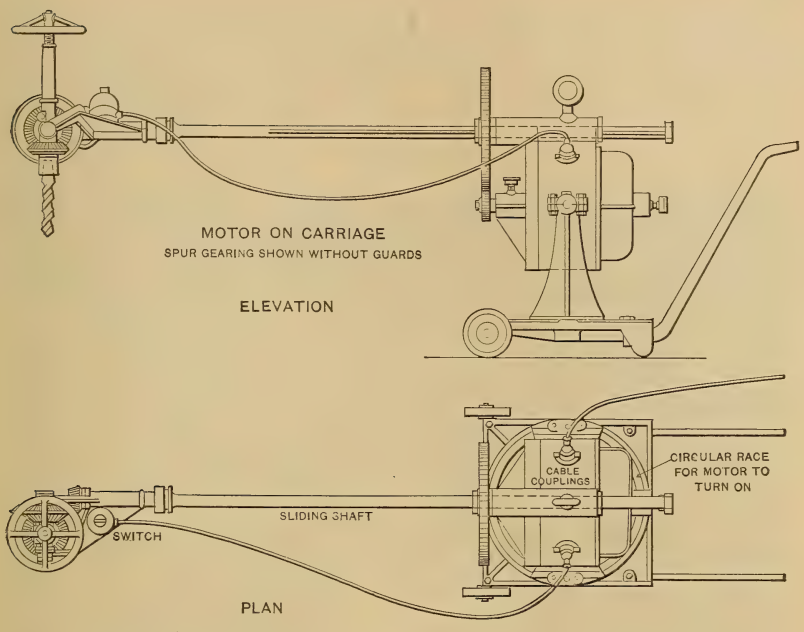


FIG. 13 —DIAGRAM EXPLAINING THE GENERAL ARRANGEMENT OF THE CAMPBELL & ISHERWOOD DRILLING MACHINE

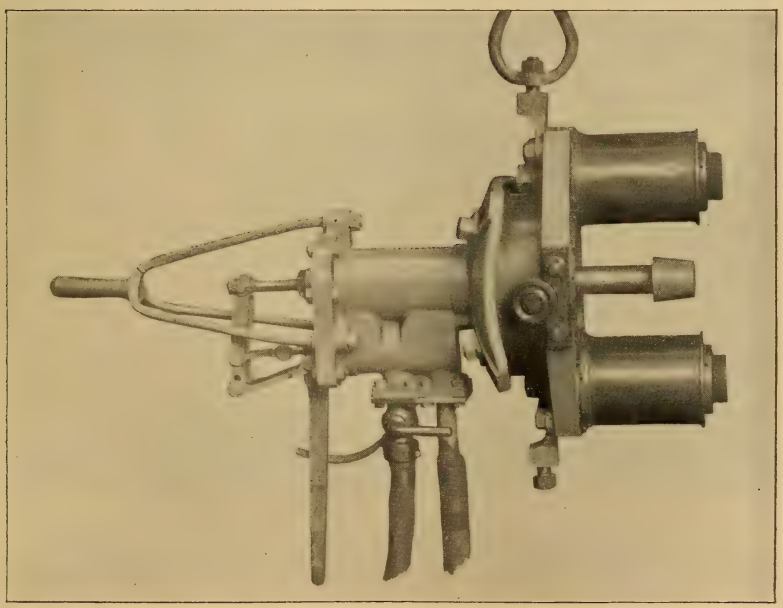


FIG. 14.—ONE OF ROWAN'S ELECTRO-PNEUMATIC RIVETERS. EITHER COMPRESSED AIR OR STEAM MAY BE USED IN THE RIVETING CYLINDER

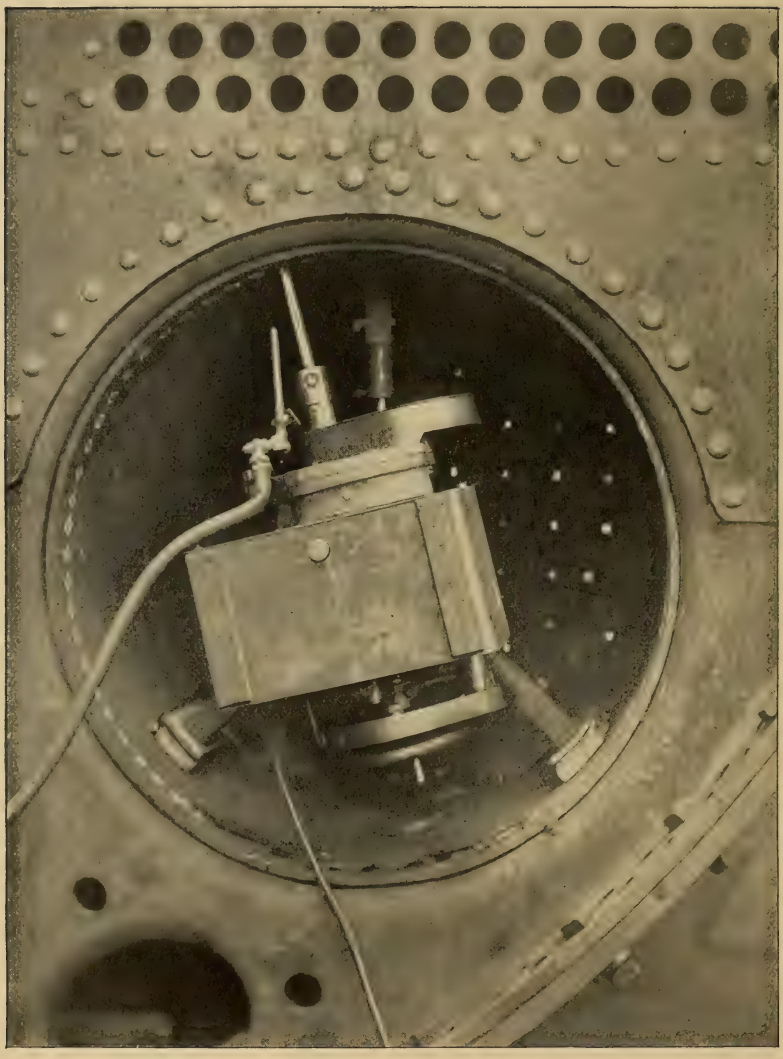


FIG. 15.—DRILLING HOLES RADIALLY IN A BOILER FURNACE FLUE, WITH A ROWAN ELECTRIC DRILLING MACHINE

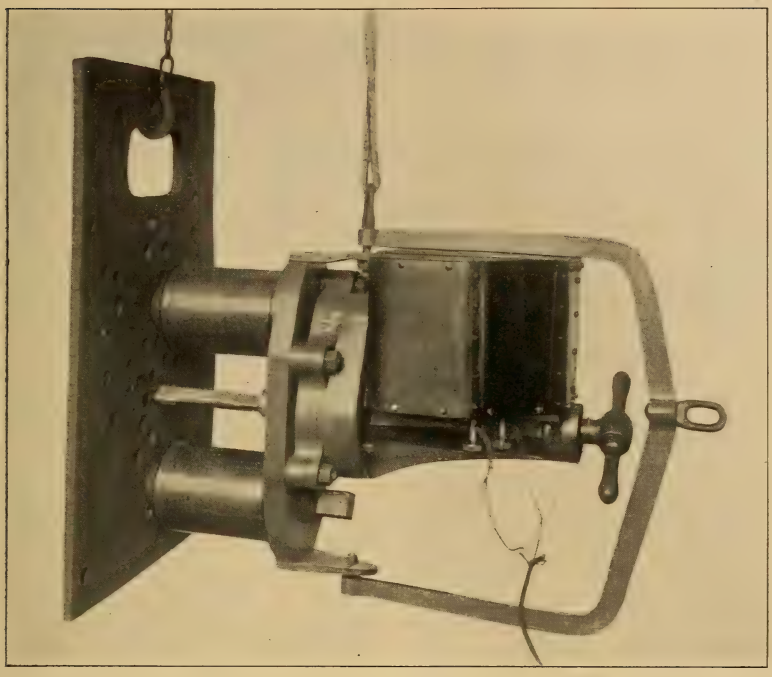


FIG. 16.—A ROWAN ELECTRO-MAGNETIC DRILLING MACHINE DRILLING A PLATE, BOTH MACHINE AND PLATE BEING SHOWN SUSPENDED

mand an appliance enabling them to carry out, with neatness and despatch, the repairs usually necessary in the event of a breakdown.

Fig. 12 shows this type of portable drill boring boiler holes. The outfit consists of an electric motor and sliding shaft with a universal movement drill head. The motor is carried on two horizontal centres by a frame which may be moved at will in a complete circle on the carriage proper of the motor. The carriage is furnished with suitable handles and wheels, to permit of easy movement from place to place, and on the top of the motor is a bracket carrying a hollow shaft. A spur wheel is provided at one end of this hollow shaft, and is driven from a pinion on the armature shaft. A long shaft slides through the hollow shaft, and on the extreme end of this is connected the drill head. The long shaft is slotted for nearly its whole length, and this slot fits a key on the inside of the hollow shaft; thus the motor drives the hollow shaft by means of a key and slot, and the motion is transmitted to the drill-head.

It will be noted from the illustrations that the drill head is constructed with two pairs of bevel wheels, four in all, in such a manner that the drill may be turned through a complete circle in a plane at right angles to the long shaft, and through almost a complete circle in the same plane as the long shaft. Directly on the drill-head is mounted a switch for stopping and starting the motor, thus giving instant control to the man who is drilling. This drill will bore holes in steel up to 1½ inches in diameter, and the motor has a capacity of 1½ brake-horse-power, taking approximately 1300 watts of electric energy. The motor is a direct-current machine, and operates upon a continuous-current circuit of 500 volts pressure. It weighs 240 pounds, while the carriage weighs 138 pounds, and the shaft and drill-head, respectively, 24 and 44 pounds.

THE TECHNOLOGY OF PAINT AND VARNISH

By Alvah Horton Sabin

THE word paint used in a technical sense brings to mind an oily fluid of which the predominating characteristics are the stickiness and odor of the oil or varnish, and the colour or staining power of the pigment which it contains. When the artisan is applying varnish he puts up a sign warning passers-by to beware of paint, which shows that by the average man varnish is regarded as a species of paint. The two are, indeed, closely related, but it will surprise most people to learn that while varnish is a product known in very remote ages, paint, as used to-day, is of comparatively recent origin.

It is no doubt true that pigments have been used from the earliest times, and are now used by all savages, for decorative purposes, and a sort of paint for architectural work is of great antiquity; but the paint used in ancient Babylon and Nineveh, and in Pompeii, was composed of pigments mixed not with oil but with water to which had been added a little glue, egg-albumen, or perhaps sometimes casein, which is albuminous matter from milk, or the gluten from cereal grains. Glue, however, which was as well known to the ancient Egyptians as it is to us, was the most universal binding material. Such paints are now known as fresco paints, or water-colours. They have not gone out of use as is illustrated by the reported statement that the New York rapid transit subway walls are to be painted throughout with some of these preparations.

The binding material in ordinary paints is linseed oil, which has the property of being able to absorb oxygen from the air at ordinary temperatures, especially if spread out in a thin film, and is thereby converted into an elastic, tough substance known to technical chemists as linoxyn, and usually called oil-rubber. It is far less elastic than India-rubber, but much more durable. This solid oxidised oil holds the particles of pigment together, protects them from atmospheric influences, and adheres with great tenacity even to a smooth metallic surface. When applied to wood or other porous objects, it penetrates the pores, sometimes carrying with it some of the pigment, and being thus protected by the solid matter of the wood its natural durability is greatly increased.

Paints are not coloured liquids, like dyes, but owe their colours to various pigments, mixed with, but not dissolved in, the oil or other liquid, which is technically called the vehicle, medium or, by artists, the tempera. These pigments are composed of solid particles,—sometimes chemical precipitates such as chromate of lead, or chrome yellow; sometimes a mineral, such as oxide of iron, ground in a mill to an impalpable powder. For technical purposes these should be fine enough to pass through a brass wire sieve of two hundred meshes to the linear inch, but for artists' use they should be much finer, so fine that there is no practicable way of designating the minuteness of their particles. Thus white lead is commercially made so fine that it passes freely through the finest silk bolting-cloth.

Pigments are usually ground in a stone mill, the primary form of which is a smooth stone slab on which the pigment is pulverised by rubbing with a smaller stone, called a muller. The oldest existing treatise on painting is that of Cennini, which describes the art

as practised in the fourteenth and beginning of the fifteenth centuries; this is his direction for grinding colours:—

"Procure a slab of porphyry, which is strong and firm; and if you procure a slab well polished it will be better than one with less polish. It should be about a foot square. Take another stone, also of porphyry, smooth on one side and raised on the other, in the shape of a porringer, and half the height of one, and with that stone which you hold in your hand break the pigment into small pieces. Put some clean water to the colour and grind it well for half an hour, or an hour, or as long as you please; but know, that if you were to grind it for a year, so much the better would be the colour. Then take a flat piece of wood, part of which is pared thin, like the blade of a knife, and with this blade collect the colour neatly; keep it liquid, and not dry, that it may flow well on the stone and be thoroughly ground; then collect it carefully. Put it then into a small vase, and pour water on it till the vase is full and keep it well covered from dust."

The colour of a pigment is due to the kind of light which it reflects, and this is influenced in some cases by the nature of the medium in which it is ground. Thus, there are many white powders, for a colourless substance, like glass, when powdered, reflects white light; but when the powder is wet with water or oil, the index of refraction of this liquid is so near that of the solid that the latter transmits the light instead of reflecting it, and is transparent instead of an opaque white. This is true of most white minerals, such as marble or chalk; but if these are mixed with a watery size and applied to a surface, the water soon evaporates, and the cementing material is too small in quantity to interfere with the colour, and so it appears white when dry, as is seen in common calcimine; but if it is ground in oil the latter solidifies but does not evaporate and the pigment remains transparent. Practically there are but two pigments which are white in oil, white lead and white zinc. This shows that the effect of fresco painting is very different from oil painting, and may admit of different pigments and handling. Water-colour painting is "flat," that is, lusterless, as compared with oil.

It is obvious that those colours which were applied with a watery medium, or vehicle, would be likely to be washed off by the rain. In a dry country, like Egypt, this was not a very serious objection and in a country which, though not arid, has a dry climate, such paintings last well indoors; but they were liable to defacement, and this led to their being protected by an insoluble glaze, that is, a varnish. Thus it came to pass that varnishes were used long before painting with oil was thought of.

The varnishes now used for this purpose are usually spirit varnishes, which are composed of a resin dissolved in alcohol or some other volatile medium; but it does not follow that these were first used, for alcohol, and in fact the process of distillation, was not discovered until comparatively recent times. The oldest varnishes we know anything about are those on wooden mummy-cases, not less than twenty-five hundred years old, and these, though they have not been chemically analysed, have the appearance of being oleo-resinous in composition.

It may here be said that oleo-resinous varnishes are made of linseed oil and resins. They owe their brilliancy and hardness to the latter, their toughness to the former, and their durability to the union of the two. Linseed oil is made from flaxseed by the simple operation of pressing the seed in a press. It is common practice to grind and heat the seed, but the best oil has always been made by cold pressure. While we have no historic mention of flaxseed oil among the Egyptians, we know that they used great quantities of linen, which is, indeed, of prehistoric antiquity; hence, they must have gathered and stored the seed. We know also that they made olive-oil, which is one of the most ancient articles of food; hence they had oil-presses; and it is quite probable that having the apparatus and the material, and being familiar with the process, they may have put the two things

together. At any rate they had the varnish, and we know of no other materials of equal durability. To the writer the evidence seems conclusive.

Pliny, writing before the Christian era, states as a matter known to everyone, that "oil dissolves all resins"; and resins have never been dissolved in oil, so far as is known, except for making varnishes. Pliny also says of Apelles, a Greek painter, who lived about the time when the Egyptians were preparing the mummies just mentioned, that no one could equal his skill in the use of varnish, with which he protected his pictures and increased their beauty.

It is well known that the early Greek sculptors coloured their statues. This was done not by the sculptors themselves, but by artist painters whom the sculptors employed. Praxitiles, when asked which of his statues he valued most, said, "those which had been painted and polished by Nicias," and in the original the phraseology is such as to imply that they were varnished and rubbed to a finish with the palm of the hand exactly as is done on fine work to-day.

Besides the oleo-resinous varnishes there are those made by dissolving resins in volatile solvents. Shellac dissolved in alcohol is the most important of the alcoholic varnishes, and dammar dissolved in turpentine is the chief essential oil varnish. Oil of turpentine, or oil of cedar, as it was formerly called, was known long before the modern practice of distillation, being described by Herodotus as used by the Egyptians in embalming. The crude turpentine was heated in a pot, over which a woollen fleece was suspended on a grating. In this the volatile oil condensed. This process was known to the Greeks, and the residuum, which is colophony or resin, was known as Greek pitch. It was not only actually, but relatively, a far more costly article than it is to-day. Some of these varnishes were probably known to the ancients, but they have not come down to us because of their lack of durabiltiy.

In their use the solvent serves only as a mechanical means of spreading the unchanged resin in a thin and uniform film. These varnishes are often called lacquers. The word lacquer is derived from a Latin word meaning a ceiling, because it was a mark of luxury in the time of the Roman emperors to have the ceilings decorated and varnished. Pliny, lamenting the degeneracy of the time, says that formerly not even the ceiling of the Senate was treated in this way, but now every rich man has his dining-room so adorned. In much later times Lord Bacon remarked that varnish makes ceilings not only shine, but last.

The advantage of a spirit varnish is that it dries rapidly by the evaporation of the solvent, while an oleo-resinous varnish dries by oxidation, and, therefore, more slowly. Also, some surfaces act on, or are acted on by, a varnish containing oil, to which a spirit varnish may be safely applied. The most recent of these varnishes are the pyroxylin lacquers, made by dissolving some form of nitrated cellulose in amyl acetate. These make films of extraordinary thinness, but remarkably continuous and durable. They are used chiefly for lacquering metal surfaces, the brilliancy of which they hardly diminish.

The resins used in making oleo-resinous varnish are of vegetable origin, and some are said to be collected from the trunks of living trees; but by far the most of them are found in the earth, the trees which produced them having died, fallen, and decayed, and the lumps of resin having become gradually buried in the soil where they have remained for hundreds or perhaps thousands of years. In some cases these lumps are found to contain insects, which were buried in them when they had the consistency of a soft balsam; and their antiquity is shown not only by the hardening of the resin but also by the fact that the insects, of which hundreds of sorts have been found, belong to species now extinct. These resins which are found in tropical and sub-tropical regions are collected by the natives and sold to the traders, who sort and clean them before shipment. The price of standard kinds have doubled in the last fifteen years,

the supply failing to keep pace with the increasing demand.

The apparatus of the varnish-maker is simple. It consists of a cylindrical, flat bottomed copper kettle, three feet in diameter and three feet deep, loosely mounted on a low four-wheeled truck which may be drawn about by the workmen. The kettle is provided with a loose cover in which holes are made to receive the stirring-rod and to facilitate the escape of gases. The stirring-rod is a slender steel rod with a wooden handle, about five feet long. The thermometers used in regulating the temperature of the kettle's contents are about three feet long, protected by well-made brass cases.

In the kettle the operator first puts the resin, one hundred pounds being the standard charge, though one hundred and twenty-five pounds are more frequently used. The kettle is then wheeled over a hot coke fire which is built in a fire-pit, under, or adjacent to, a chimney with a flue of from ten to twenty-five square feet cross-section. This chimney creates a draught of great volume, necessary not so much to carry off the products of combustion, for very little fuel is used, as to remove the vapours generated in melting the resin, which are very acrid and irritating as well as highly inflammable. The kettle is kept over the fire about half an hour, or until the resin is all melted, which the varnish-maker knows by feeling the liquid to be smooth as he stirs it, and by looking at drops of it which he withdraws on the stirring-rod. The temperature rises to about 600 or 700 degrees Fahrenheit.

When all is melted, the kettle is drawn from the fire, the cover lifted off, and a quantity of hot linseed oil is gradually added. If it is desired to make a hard and brilliant varnish, the amount of oil may not be more than eight or ten gallons to the hundred pounds of resin weighed before melting; but if it must have more elasticity, more oil is used, and for a varnish to be exposed to the weather, as on the outside of a carriage or a yacht, as much as twenty-five or thirty gallons is employed.

When the oil is all in, the kettle is put back on the fire and the mixture is cooked until its components have thoroughly united. If this operation is not sufficiently carried out, the resulting varnish will lack some of the durability that it should normally possess; if carried too far, the product will be too thick and will require thinning with spirit of turpentine to an excessive degree, causing too thin a final film.

When properly cooked, the kettle is removed from the fire, and when it has cooled down to about 300 degrees F. enough spirit of turpentine is added to make the varnish, when cold, of the proper consistency to flow out under the brush. The amount of cooking, the range of temperatures, and the quantity of turpentine needed are all empirically determined for each kind of varnish. It is then kept in tanks for several months, when it is found to be clear and ready for use.

It is obvious that the fundamental differences in varnishes are due to the different proportions of oil added to the unit amount of resin; but the colour depends chiefly on that of the latter ingredient, as do also, to a considerable extent, the hardness, luster, durability, and all other qualities. The selection of the resin, which is the most costly material, is, therefore, a matter of great importance. In early times amber was used, and we have recipes coming down from the tenth or eleventh centuries, describing the process exactly as given above, except that glazed earthen pots were used--they were still in use a hundred years ago—and very small quantities of varnish were made.

The use of paint brushes is of great antiquity; but as late as the fifteenth century it was customary to apply varnish by smearing it on with the fingers or with a bit of sponge, as the varnishes then used were too viscid to flow well with a brush and could be put on more thinly and evenly with the fingers. This practice was used in the earliest times of which there is any record. The Egyptian mummy-cases bear evidence of having been varnished in this manner.

The use of fresco, or water-colour,

paints, though the oldest, was not the only method known to the ancients; the Greeks and Romans especially practiced encaustic painting. Encaustic paints were made of clarified beeswax, with which, when melted, pigments were mixed. These paints were applied hot, with brushes or spatulae, and when cold they were given a glazed surface by holding a torch or a hot iron near them. The hot iron was called the "cauterium."

Another method is said to have been to melt the wax with resin, and after the pigment was added, the compound was allowed to cool to a hard and brittle mass which could be pulverised. The coloured powders made in this way were mixed with water, so that they could be applied with a brush like fresco paint; after which they were melted by the cauterium. If resins were thus used with the wax, a sort of varnish was the result; if the wax was used alone, the finished painting was sometimes varnished. These coloured waxes were also used for writing; the red especially was used for royal signatures, whence the use of red sealing-wax for a seal; and this "incausticum," as it was called in the Middle Ages, is the origin of our word ink.

Encaustic paintings were used chiefly on walls. Their effect was more brilliant than that of water-colours, and as wax is comparatively indifferent to lime, they adhered to the walls better than oil or varnish paints.

Jan Van Eyck, a Flemish painter, at the beginning of the fifteenth century, is commonly said to have introduced the practice of oil painting. Two exceptions may be made to this statement,—he did not practice oil painting, and that which he did practice, namely the use of oleo-resinous varnish as a vehicle, he did not originate.

The use of varnish paints, that is, pigments ground in varnish, as a vehicle, had been known, especially in the useful arts, for a long time; but no artist of great prominence had adopted it. Van Eyck was a painter of the highest class, both as regards taste and skill. His adoption of this medium and the surpassing results he achieved with it, established its pre-eminence at once among his contemporaries and successors.

A painter's studio in those days was also a laboratory and a workshop. Painters' apprentices worked, according to Cennini, six years at the purely mechanical part and seven years at the artistic, before they were qualified to undertake original work. They made ready their own canvas or other surface on which to paint, including the preparation of walls and ceilings. They learned to gild, to make pigments, to prepare oil from the seed, to make varnish, and the liquids for fresco painting, including the manufacture of glue. After a repast they picked up the bones which had been thrown under the table, to be calcined and used in making preparations for filling the irregularities of the surfaces on which they were to paint.

The varnishes made by the great masters of the Middle Ages were rich in oil, containing probably not less than three times as much oil as resinous matter. Such varnishes work very freely under the brush, and the paintings were incomparably more brilliant than those in distemper or fresco, for it must be remembered that water-colour painting had not at that time been forced by such extreme practices as are now in vogue to imitate the depth natural to oil and varnish.

The pigments were mixed directly with, and thus immediately protected by the varnish, and the pictures did not require, as do oil paintings, a final coat of varnish which tends, on the whole, to lessen their brilliancy. Thus were made all those celebrated works of art which have come down to us from those remote times, possessed of a durability which modern painters have given up in exchange for the greater freedom and "sweetness" of working quality allowed by the use of unmodified oil as a medium.

Varnishes are viscid liquids. They are thinned with turpentine to increase their fluidity, and in general those rich in oil work more freely than those with

much resin, but in this respect they are never equal to pure oil. As the latter is more fluid, the paints made with it may, and commonly do, contain more pigment than the corresponding varnish paints; hence they have greater covering power, not that they cover more surface, but the painted surface contains more particles of pigment and a less quantity of medium or vehicle per square foot than is the case with varnish paints. If the oil paint were made with no more pounds of pigment per gallon than the varnish paint, it would cover more surface, but of course with a thinner film.

Paint and varnish are used for two purposes,—for decoration, and for protection against atmospheric and other sources of injury. The value of pigments as protection is three-fold:—They thicken the liquid and hence make it possible to apply a thicker film; being solid particles, they make a harder film, which better resists abrasion; and the particles of pigment fill up some of the pores of the film and thus make it more continuous. These films are very thin, usually from one to three one-thousandths of an inch in thickness, and are somewhat porous. A second application greatly decreases the porosity by covering up the holes in the first coat; three coats make a still better protection; less than two should not be used.

When oil oxidises, it remains liquid for a long time, then suddenly gelatinises; further oxidation causes this film of gelatinous oil to shrink in volume, though it increases in weight, and this shrinkage causes the film to pull apart and become porous. If, therefore, we can prevent or defer this gelatinisation we will make the film more nearly non-porous. This can be done only by adding something which will act as a flux. The only thing which can be dissolved in oil without injuring it is resin, and the varnish resins do act as a flux, deferring, if not preventing, the gelatinisation of the film. This is probably the principal reason why a well-made varnish film is less porous and more durable than an oil film.

Not all varnish films are more durable than oil, for if a large proportion of resin is present, the coating, though at first impervious, after a little time shows cracks, perhaps because it is too hard and inelastic to stand changes of temperature. The varnishes used by the painters of the Middle Ages, as well as those of ancient Egyptians, show a durability which no oil film can be expected to attain.

Oil paints, however, penetrate wood more readily than varnish; have greater covering power; are somewhat easier to apply; and are cheaper. They are good paints if well made, and it is easier to make a good oil paint than a good varnish paint. No varnish paint can be made for the same price that an equally good oil paint will cost, and this is argument enough with most people for the use of the latter. On the other hand, the varnish paint may have the greater durability, be the more economical in the end, and look better always.

What are sold in the market as "ready mixed" or "liquid" paints are paints ground in oil, of the right consistency to apply. Usually they contain a little varnish to give them a gloss. They are intended for house-painting. The best of them are excellent paints, made with the aid of the highest professional knowledge. The chief difficulty with them is that people are too willing to buy an inferior article because of its lower price.

Linseed oil, in its natural condition, requires five or six days to dry; it has, therefore, become a general practice to add to it something to accelerate this process. Compounds of lead and manganese will do this, and hence are called "dryers." Dryers must be such compounds as will dissolve in the oil. The best of them are made by heating the oxides of these metals with linseed oil, or sometimes with a mixture of oil and some resin, until combination takes place and the metal dissolves, as linoleate or some such compound, in the oil. About two per cent. of lead, together with a much less quantity of manganese, makes the oil dry in twelve to twenty-four hours; such oil is called boiled oil. It is possible to combine these oxides

with oil to the extent of about twenty-five per cent., and this compound dissolved in turpentine or benzine to a rather thin liquid, is called a "liquid dryer" or a "japan dryer."

The use of these preparations is attended with great danger to the permanence of the paint, and is the most common cause of its failure. They should never be used to the extent of more than 2 to 5 per cent. by volume, and should never be used at all with prepared paints, to which the maker has already added the proper amount; nor ever with varnish, which they will immediately ruin.

The current practice in commercial work is to use paints ground in oil, with or without the addition of a small amount of varnish, but always with a little dryer, for exterior and for the most of interior house-painting. Varnish paints are used on some high-class interior house-painting and almost wholly on interior yacht-painting. Carriages, railway coaches and the like are painted with "coach colours,"—quick-drying paints ground in "japan," a sort of varnish heavily charged with dryers, and then given several coats—often half a dozen—of varnish; but freight cars are painted with oil paints exclusively; bridges and other steel structures, usually with oil paints, more rarely with varnish, or in special cases with some really high-class varnish paints. In this last class the practice does not seem to be on a satisfactory basis, for some paints which are good on wood are not permanent on an absolutely non-porous surface like steel, which is, besides, extremely sensitive to chemical action.

Artists paint with a variety of mediums, of which the best is probably plain linseed oil; to this they add various dryers, called "siceatif," and sometimes a mysterious abomination called "megilp," which originally was a mixture of oil and (alcoholic) mastic varnish. When dry, the paintings are varnished with a spirit varnish; the chief merit of which is that when it gets to looking dingy it can be washed off with alcohol and a fresh coat applied. The results are certainly very pretty, and brilliant.

It may be said in general, both as regards technical and artistic work, to those who think we have lost the secrets of making the preparations of great permanence which our remote predecessors used, that what we have lost, perhaps forever, is not knowledge, but patience.

THE WIDENING USE OF STEEL CASTINGS

IN THE UNITED STATES

By W. P. Barba

THE workers in the whole field of engineering and mechanics are constantly seeking the best contrivances and combinations of material that will assure to the creations of the designer and manufacturer the greatest stability, ease of construction and operation, and lowest cost of maintenance and repair. Just so much as engineers rely upon, and use for these ends, rolled structural shapes, so do they depend upon steel castings; and the manufacturers are constantly called upon to produce steel castings for uses novel to the art, showing that their product is always in the mind of the designer when new work is coming up.

The severe physical requirements asked are further proof of the trust reposed in steel castings as modernly produced. What engineer, for instance, would ten years ago have allowed, if he knew it, to be placed in his structure steel castings designed for a tensile strength of 80,000 pounds? All the specifications then called for steel of 60,000 pounds and stretches as low as 12 or 15 per cent., and anyone who offered steel as high as 80,000 pounds tensile strength would probably have had his castings rejected. And yet to-day manufacturers are turning out steel castings where the minimum physical requirements are,—tensile strength, 80,000; elastic limit, 40,000; extension in 2 inches, 18 per cent. The tendency in specifications now seems to be to higher requirements,—higher carbons, and then intelligently directed heat treatment as the last operation before use.

Engineers are no longer afraid of the harder steels. The development of the art offers every assurance of good and correctly handled product, and the subsequent annealing, always provided by the careful manufacturer who studies the individual uses of his output, whether such annealing be ordered by the purchaser or not, has given designers far more confidence in steel castings than has ever been enjoyed before. That this confidence is not in any way misplaced, the instances of modern use of steel castings to be hereafter set forth will serve to indicate.

To speak further of the harder steels necessarily brings up the question of the new high-speed tool steels, without which the harder steels would meet with much opposition in the machine shops because of the slow progress in machining. Even on the ordinary softer castings, as more generally furnished, the cry is raised by the machinists that "they cut hard," while with the self-hardening tool steel properly handled, as is now so well understood, this complaint is seldom heard.

This matter of high-speed tool steels is responsible for one of the newer uses of steel castings, in that the old machine tools when driven hard, removing far more metal per hour than was ever dreamed of when their design was put forth, cannot stand the strain, and are giving way in every direction. First one part is strengthened by the substitution of a steel casting for the iron primarily used; this part transmits its in-

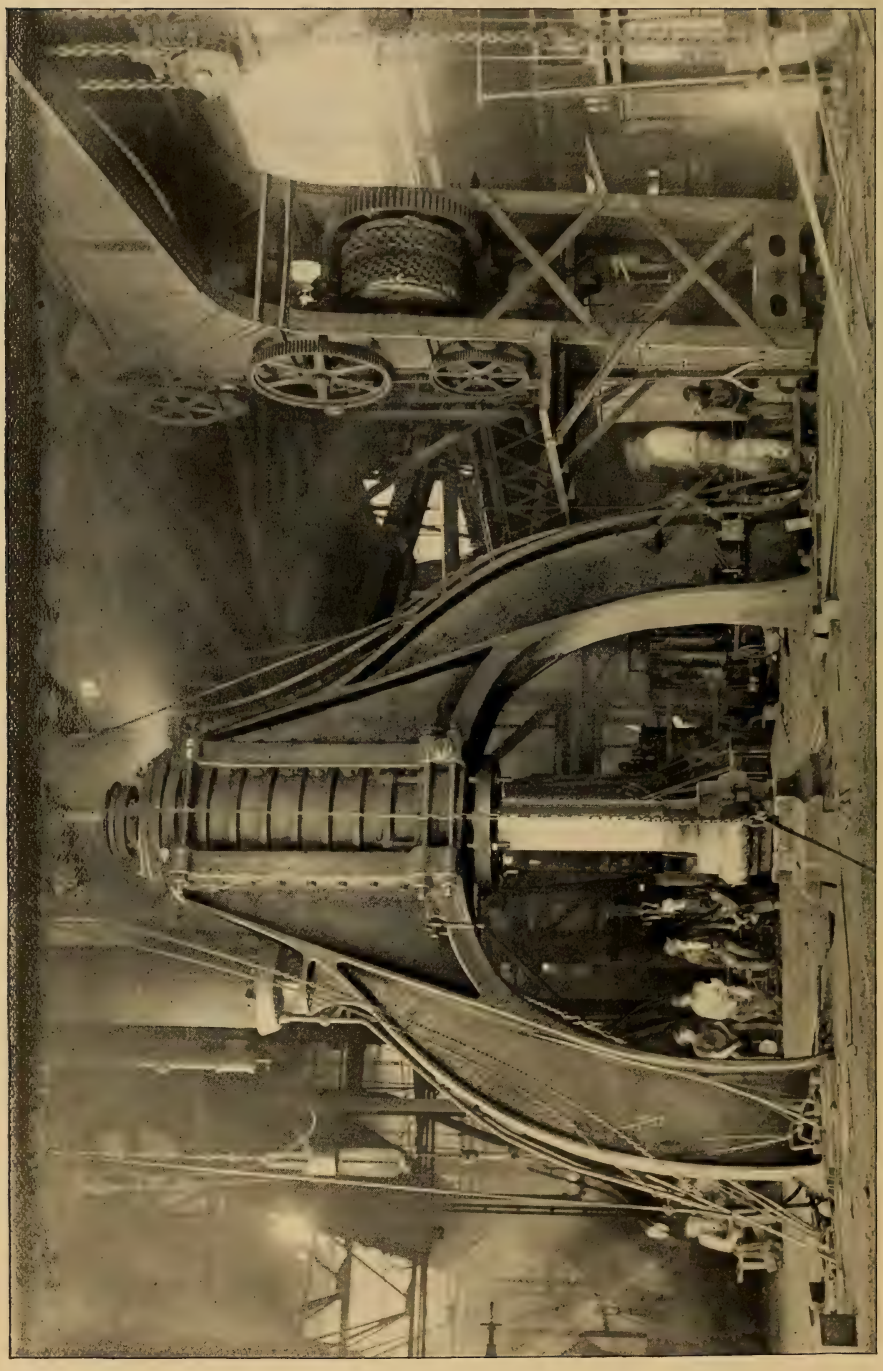


FIG. 1.—THE WHOLE HAMMER IS MADE UP OF STEEL CASTINGS. THE TWO LEGS EACH WEIGH 32,000 LBS. AND THE CYLINDER WEIGHS 35,000 LBS. THE TOP FOUNDATION FOR THE ANVIL BLOCK IS A STEEL CASTING OF 105,000 LBS. WEIGHT

creased load easily to the next, and that breaks down in its turn, with consequent replacement with steel, and so on,—the old story of every repair job under increased pressure of operation. Then the builders of machine tools redesign their machines, perhaps allowing more weight in the cast iron parts, but certainly replacing many of them with steel castings, thus giving at first the maximum of stability to their designs.

Another example of this enforced substitution of steel castings for iron castings may be found in the framing of steam hammers, both large and small. One of the best known makers of steam hammers began turning out whole frames of single-leg hammers about two years ago, and it would seem that by cutting down the section slightly and offering a tool of less weight at an advanced price, because made of steel castings, a good stroke of business was accomplished. It may be advertised as a fact that the steel casting perfectly withstands the severe vibratory strains which so frequently cause failures in the cast iron hammer legs.

In one works, intimately known to the writer, and in which seventeen steam hammers are used, of from 500 pounds to 100 tons capacity, it was found not only desirable, but necessary, to substitute a complete steel structure for the larger sizes of ordinary forging hammers. Fig. 1 shows a type of hammer that for four years has been working constantly, two shifts a day, and without any repairs to its structure.

The whole hammer is of steel castings, two legs and a cylinder. No change was needed to produce the cylinder casting from the pattern built for iron castings, save to allow for the greater shrinkage and to uncover the back of the steam port openings to permit ready removal of the cores, fully enclosed cores such as these not being as readily cleaned out of steel castings as from iron. This opening was afterward closed by simply studding on a flat casting properly packed.

This hammer is one of four built of steel castings, and the experience before this time was the same as outlined above when speaking of machine tools. First a flange on a leg would crack and be patched; then another; then a flange on the cylinder face, and the whole would be held together once more with heavy patches of steel castings and strong through-bolts. The final substitution of all steel was at once indicated, but the difficulties of the practical manufacture of steel castings of shapes so intricate in moulding were too apparent for their immediate adoption. These difficulties, however, were successfully overcome, and all four hammers,—three of ten tons and one of four tons,—are now provided with steel castings for their main parts.

While speaking of hammers the matter of dies is naturally suggested, and it will be noticed that for all ordinary forging work steel castings are now used for hammer dies to the exclusion of cast iron. The selection of the proper material for these dies is one of great moment to the user, and should be most carefully gone over with the manufacturers, as the grade of material suitable for one kind of service would be utterly unfit for another. For example, a plain face die of about 400 pounds weight might be made of metal of a certain hardness and give most excellent service; while a swage or *V* die, made on the same heat, and of the same composition, would be found entirely too hard, resulting in early fracture. This instance is given as one of many where full co-operation between user and maker would prove of great service.

Heads for drop hammers are now being made of steel castings where before nothing but cast iron was used. These castings, of all weights, are giving most excellent service. The dies for drop forge work, where forgings of large size and deep impressions are made, also consist now largely of steel castings. Much care is necessary to get the correct hardness for each class of work, as too soft dies will give no service.

A kindred use of steel castings to those in steam hammer work may be found in the newer riveting machines,—the large ones for boiler shops, 20 feet in the throat and weighing up to 40,000

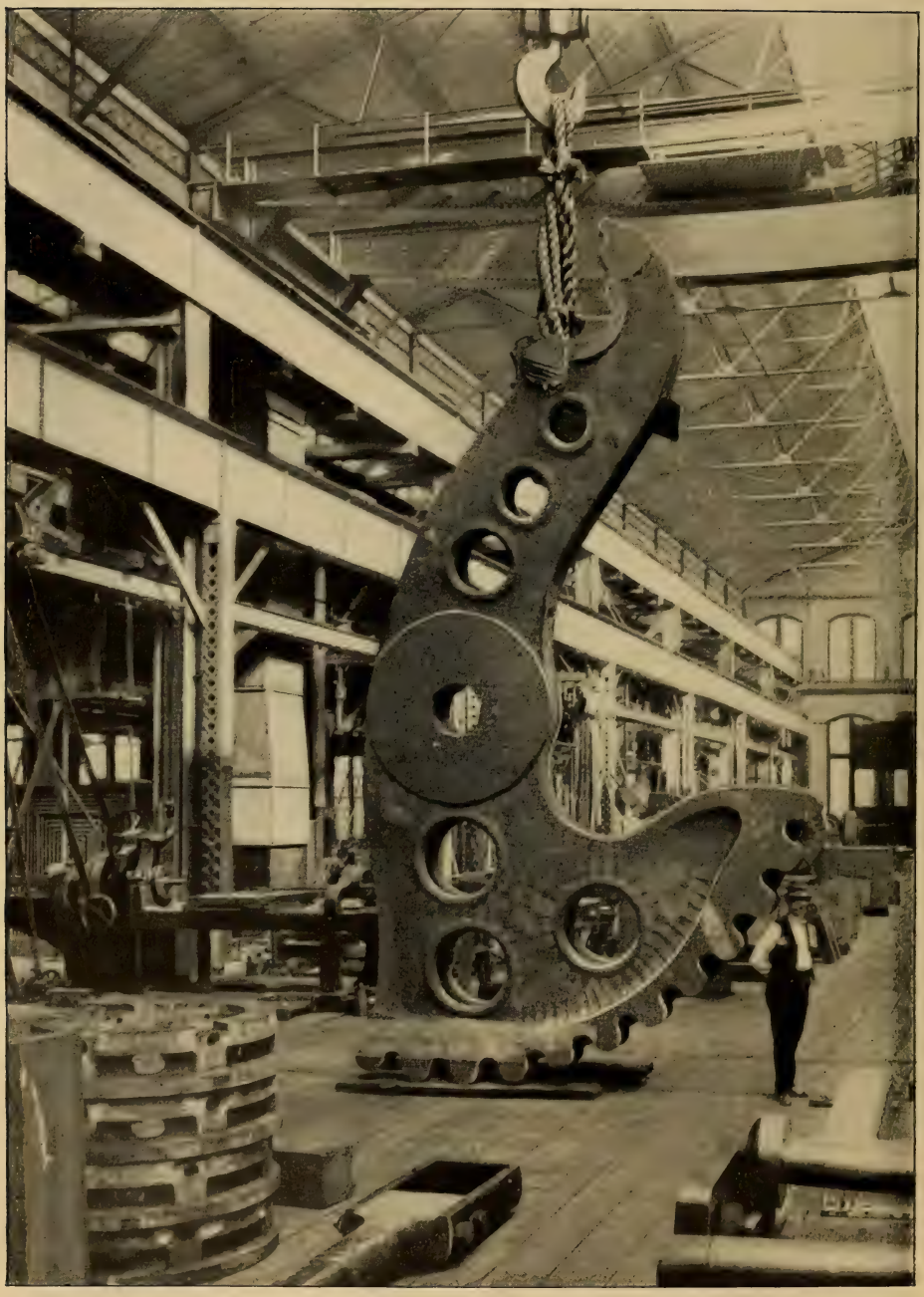


FIG. 2.—ONE OF THE TWO CAST STEEL ROCKER ARMS FOR THE CARRIAGE OF THE 16-INCH UNITED STATES ARMY GUN AT SANDY HOOK. LENGTH, 23 FEET; WIDTH, 14 FEET; WEIGHT, 30 TONS

pounds per casting,—which are doing work never before attempted, and which would be impossible without the steel casting. There again the harder steels come into service, as the deflections permissible in these long riveters are so small that the softer steels will not answer the requirements, and, when used, broken dies and other troubles result. Thorough and intelligent annealing of these important parts cannot be too strongly urged. The smaller castings of the riveter class are found in all the outdoor lines of engineering work, made necessary by the erection, in place, of so much of the ironwork now going into great structures, trolley lines, etc. Punches and riveters, both hydraulic and pneumatic, have for their main part a strong yet light casting of high carbon steel.

The heaviest steel castings,—not the largest,—thus far made in America were recently finished, being the top and bottom and heads of a great forging press, and weighing upwards of 200,000 pounds per casting. The largest, 33 feet by 16 feet by 50 inches deep, weighing 165,000 pounds, has just been made, and is one of two chassis girders for the mounting on a disappearing carriage of the 16-inch gun recently sent to Sandy Hook. Fig. 2 shows one of the components of this carriage, being one of the two rocker arms, 23 feet long and 14 feet wide, each weighing 60,000 pounds. The gun is mounted in the upper jaws. The whole carriage, when finished, will contain no less than 1,100,000 pounds of steel castings, and would be an entirely impossible construction were it not for the facility with which such dependable steel castings are now being produced.

Ordnance work in general demands steel castings without limit, although the army conditions permit greater weight of parts in fortification work, and, therefore, more cast iron is used there than in naval work. Still, as instanced above, great quantities and great masses of steel castings are used. There will probably be upwards of 500 sets of high powered rifles mounted along the United States sea coasts in the Buffington-Crozier type of disappearing gun carriages; each of these of 12-inch size uses 128,000 pounds of steel castings, and the importance of the work they are called upon to perform, and the extreme rigidness of inspection during manufacture, together with the high physical requirements specified, remove this class of castings from the competition of all but a few of the very best manufacturers of steel castings in America.

In naval mounts, in which every pound of added weight is jealously watched and penalised by loss of engine power, the question of steel castings becomes even more important, and the greatest nicety of design and construction is practised. The mounts for all the naval guns, from the humble one-pounder up to the imposing 13-inch turret gun, are made up entirely of steel castings, and, as every pound of excess weight is rigidly pared from the design, the difficulty of producing satisfactory castings to resist the enormous shock strains rises. Some of the most baffling problems of the modern steel foundry are found in these same naval ordnance castings. Nevertheless, when, in 1898, the United States Government called on the manufacturers to furnish these same castings with all speed, it was done with ease, and the auxiliary fleets were all fitted out with mounts, and in some cases with guns, which were not started till after hostilities in the Spanish-American war of that year had begun.

The modern battleship, the cruiser, or the merchant steamer depends more for its success as a structure upon steel castings than upon any other form of steel manufacture, excepting only plates and shapes; indeed, without the castings the plates and shapes would be useless. When, as in the past two years, the market for steel castings has been so glutted with orders that all users were clamoring for their castings, the shapes were entirely useless. No work on either end of the ship can be finished until the steel castings are in place, and shipbuilders now design and order their steel castings before any other class of material needed.

The character of the castings of a

modern battleship may be gauged from the statement that the lower section of the stem of the United States battleship *Virginia*, for example, weighs 57,000 pounds. The entire stern framing, the rudder head, rudder frames, steering gear, hawse pipes, chocks, bitts, etc., are steel castings in all first-class vessels, and with the development of the water-tight compartment of large size has come another use for the steel casting, namely, the framing of the bulkhead doors; both door and frame are now built upon steel cast angles, the bent shapes proving too weak for the large sizes now used.

It is in the engine department of the modern ship that steel castings find their most important use in shipbuilding, and it is there that the most difficult designs are called for. Shipbuilders are penalised as much as $500 per ton of extra weight over a given maximum for the engineering department of a cruiser, and the greatest care and watchfulness are exercised in keeping down the weights of the sections used. In consequence, much intricacy of design results. Every piece, from the heavy bed-plate or cylinder down to the smallest washer or oil cup, is weighed by government officials and entered up as a part of the engine weight before it goes into the ship. This phase of the question is touched upon to show the degree of refinement to which the designing of steel castings is now carried. In more ordinary work such care is unnecessary and costly; for, without question, those who go to such lengths of refinement are called upon to pay for it. This matter of design for ordinary work will be dwelt upon later.

Engineers engaged in transportation find in the steel casting one of their most valuable servants, and the modern locomotive, with the exception of the boiler, cylinders, axles and rods, is practically all steel castings. Several years ago, when cast steel locomotive frames were beginning to be used by Krupp in Germany, they were yet novel in America. By 1898 they were being made in the United States in numbers, and the large builders of locomotives now recommend them without hesitation in preference to the wrought frame with its numerous welds. The rapidly increasing size and weight of locomotives demands that the section of the frame be correspondingly increased, and it would seem that the limit of a successful weld has been passed. We must, therefore, come to the cast steel frame, and while a few hold out for the welded frame, they will be forced to adopt the cast steel frame as the weight of the engine rises.

These same great weights led the superintendent of one large locomotive works to propose to the writer the substitution of cast steel cylinders for the hard cast iron now used, and the inserting of a cast iron liner, which could readily be replaced, to take the piston wear. The writer agreed to furnish such cylinders, asking only that proper openings be left for the removal of the steam passage cores. None have yet been ordered, as in such a matter the locomotive builders, not the steel foundrymen, must assume the initiative.

The railways are finding their lines paralleled by trolley lines, built much more cheaply, over right of way which rarely needs to be purchased, and operated by large central power stations, often using water-power, at a cost per passenger mile far below that of the steam roads. In many ways this trolley extension is calling for extensive and novel uses of steel castings. In the first place, the many switches, turnouts and crossings of the rails in towns call for such castings in large quantity, and the supply companies are constantly pressing for delivery, first for new work and second for replacements, for the steel flanges of the wheels rapidly wear out the parts used on curves. Then, again, the cars themselves, fitted with cast steel truck frames and each equipped with two motors up to 200 H. P., use up a large tonnage of steel castings. The making of the field castings for these motors alone would keep several large casting plants constantly busy.

A step further, the generator calls for steel castings for the poles and sometimes the yokes, many of these being of great weight. Where the generator is driven by a steam engine, the use of the steel castings for the engine is but small

until the power of the engine rises to the very large sizes. Thus the 5000 KW machines installed in the power houses in the large cities are built largely of steel castings; the ponderous fly-wheels, built up of sections weighing, in one case, 35,000 pounds each, and five to the wheel, when assembled, are provided with cast steel rim weights, bringing the weight of the fly-wheel for one engine up to 300,000 pounds of steel castings.

These large engines are now menaced by a new competitor,—the steam turbine, and in this type of motor also steel castings are used to a very large extent. In one of the large steam turbines recently built, coupled to a 5000-KW generator, four large discs are used, each a steel casting weighing close to 20,000 pounds, or ten tons. These discs, when revolved at a speed of 500 revolutions per minute, put the casting under a tremendous stress. Then, again, the great power plant at Niagara started to call for heavy steel castings in 1894, and the twenty large machines now in use there are dependent upon steel castings for their success. The enormous coils and the heavy field ring revolving at a speed of 250 revolutions per minute hang from an umbrella-shaped steel casting which forms the foundation of the machine.

The various hydraulic systems now being installed all use steel castings. Where the high-head powers are used, the steel casting plays a very important rôle. The water is often brought to the wheel in a sheet-steel flume or penstock, the lower part of which, as well as all the branches, tees, and ells leading to the nozzles, are steel castings. Then, in the impact types of wheels, the body of the wheel and the buckets themselves are steel castings, and, again, the generators.

Such high-head water powers are often used for hydraulic placer mining, once so common. But there is another type of placer mining growing very rapidly in importance, too,—the dredge system. In this a dredge is built to float on even a small quantity of water, always, of course, a river or water course in a valley filled with the alluvial deposits of ages. The dredge carries a complete washing plant, through which the dredged material is passed, the gold being recovered and the tailings passed back behind the dredge. When all in reach of the dredge has been so treated, the machine is moved forward its own length and the operation indefinitely repeated. In one California district alone there are over forty dredges working, and in one district in Montana two dredges of immense size are employed, and four more, larger, are being built. These dredges have bucket chains of eighty links, each link being a steel casting of about a thousand pounds weight. The bucket lips also are steel castings, easily replaced when worn away by the severe duty which they are called upon to perform. These dredges work night and day, every hour possible, and the requirements of the engineers in charge of the work are for steel castings of the highest attainable grade of perfection.

Mining apparatus of the older sort also employs steel castings in more and more ways. The preparation of the ore for the smelters uses up many thousand tons yearly and embraces every known type of crushing mill, from the primitive Chili mill, in which the stone bed and crushing wheels of the earliest days are simply replaced by steel castings up to the well-developed Cornish mill driven by large steam or water-power plants. When the ore goes to the smelter, steel castings are again used, and when the matte is tapped it flows into a cast steel ladle, weighing in some cases as much as 12,000 pounds, and containing, for this weight, 100 cubic feet. When the copper is obtained it is either poured into moulds of cast steel for shipment as pig copper, or, in the newer processes made necessary by the demand for purer copper by the electrical manufacturers, it is poured into cast steel anode moulds, and thence goes to the vats for the electro-deposition of the pure copper, incidentally leaving in the vats enough recovered gold and silver to pay for the whole operation, steel castings and all.

The same crushing machinery used

for the preparation of ores has been adopted by cement makers, and almost as much tonnage of cast steel goes to them as to the mines. The popular cry for better roads has reached the steel casting industry, and has been answered by the production of the needed machinery for quarrying and crushing the rock, elevating and screening it, and finally putting it firmly in place by means of the steam road roller, all the machinery employed using steel castings in considerable quantity.

These are some of the more important and newer uses of steel castings, leaving the field, however, by no means fully covered. A word, now, as to the securing by the consumer of the casting best suited to his needs. It is not enough to simply get a price and ship the pattern and expect to receive in return the exact thing desired; a little consultation with the manufacturer before making the finished design, or a letter or two passing between maker and user before placing the order for the pattern, and there would be received in return, cheerfully furnished, the advice and the experience of men whose sole business it is to produce an article whose use is comparatively infrequent with the purchaser. In all cases the drawing should be sent to the foundry with the pattern, so that a further inspection and check of the pattern may be made and the rough casting be inspected for finish and dimension before shipment to the consumer.

The above simple procedure would benefit the consumer to a degree not realised by one who has not followed it, and would prevent many vexations frequently resulting from carelessly made patterns,—too often made in an outside pattern shop, and not checked by the designers. This system has been practised by the writer for ten years with entire success, and it cannot be too strongly urged upon users of steel castings to take the maker a little more into their confidence in the design primarily, in the method of pattern construction, and, so far as may be done, in the use of the piece desired. Failures and too short a life of parts often follow neglect of these recommendations.

MULTI-CYLINDER LOCOMOTIVES

A REVIEW OF THE WORLD'S PRACTICE IN MULTI-CYLINDER SIMPLE AND COMPOUND LOCOMOTIVES

By J. F. Gairns

PART III.—FOUR-CYLINDER COMPOUND LOCOMOTIVES

Parts I. and II., dealing, respectively, with "Multi-Cylinder Simple Locomotives" and "Three Cylinder Compound Locomotives," appeared in the issues for December, 1903, and January, 1904

GENERALLY speaking, there are in successful and more or less common use to-day five different methods of arranging the cylinders of the four-cylinder compound locomotive. They are,—

1.—The "balanced" system,—all cylinders abreast and driving one axle, so as to give four distinct impulses per revolution.

2.—The "divided and balanced" system,—two cylinders driving one axle, and two another, the axles being coupled, bogie, and the low-pressure cylinders driving another one.

In the following pages, the four-cylinder compound locomotives of the past and present, according to this classification, will be dealt with, excluding, as far as possible, from each section matter relating to other systems.

I.—BALANCED COMPOUND LOCOMOTIVES

Before 1883 several patents had been taken out on four cylinder compound locomotives with all four cylinders abreast

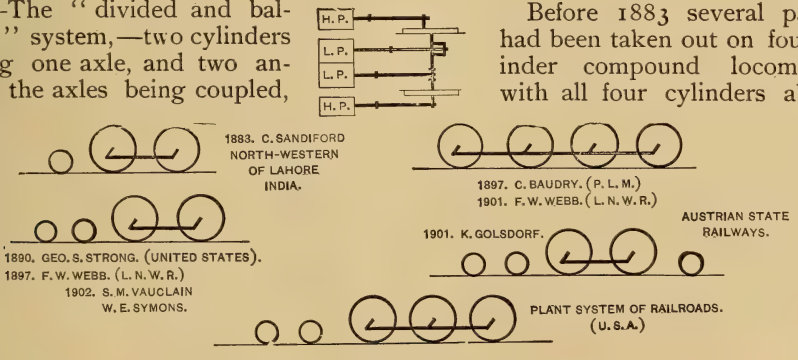


FIG. 33.—SOME BALANCED LOCOMOTIVE DESIGNS

the arrangement also being such as will give four distinct impulses per revolution.

3.—The "combined cylinder" system,—two cylinders at each side with one cross-head, so that only two sets of motions are required.

4.—The "tandem" system,—high and low-pressure cylinders at each side, end to end.

5.—The "double bogie" system,—high-pressure cylinders driving one and driving on to one axle, but so far as is known no engine of that kind was built. The suggested engines represented ideas on paper, and remained there.

In 1883 Mr. C. Sandiford, locomotive engineer of the North-Western Railway of Lahore, India (previously the Scinde, Punjaub & Delhi Railway), who has also been mentioned in connection with an experimental three-cylinder compound engine, fitted an old engine with

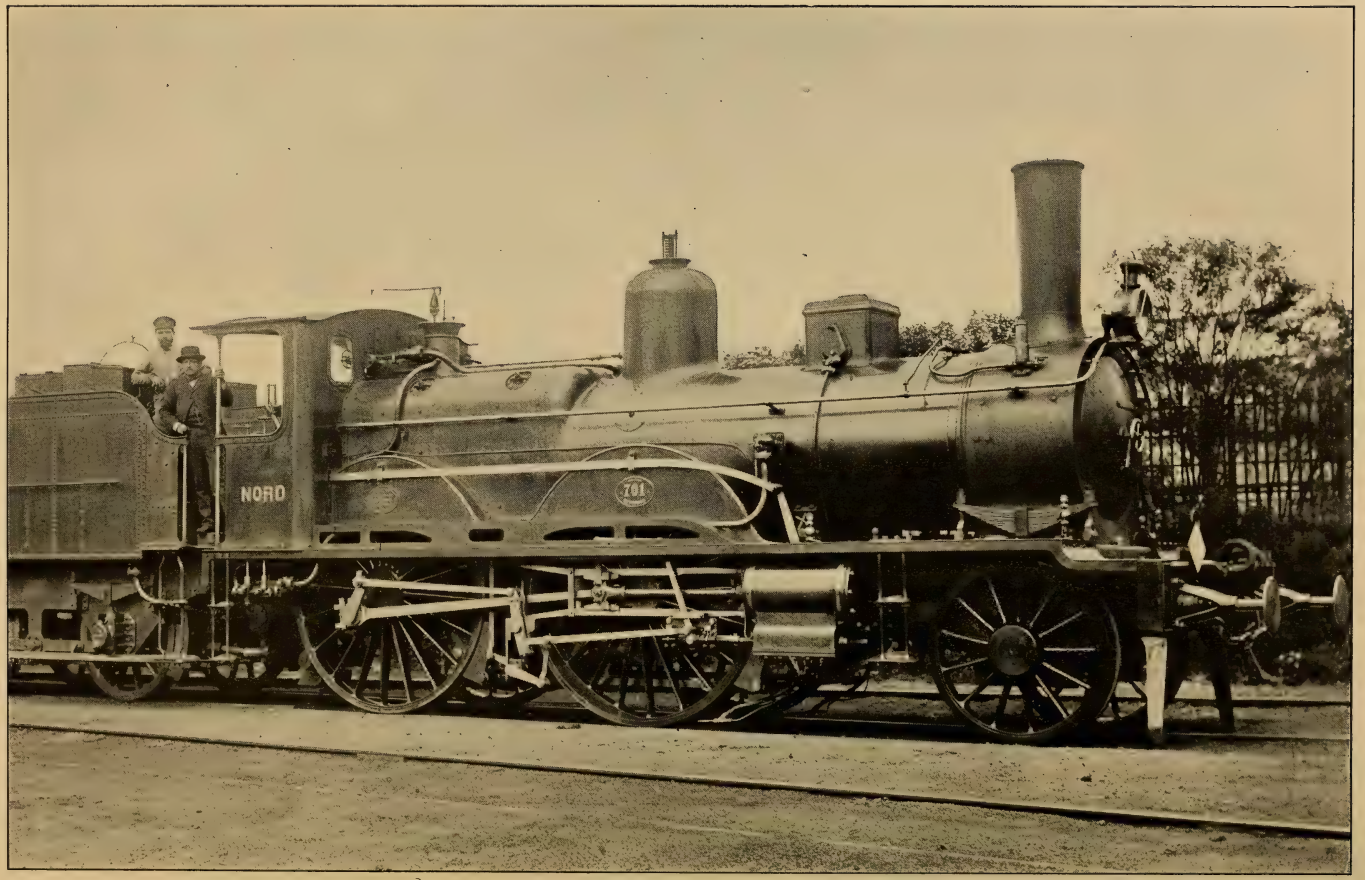


FIG. 35.—DE GLEHN'S FIRST FOUR-CYLINDER COMPOUND LOCOMOTIVE ON THE NORTHERN RAILWAY OF FRANCE. THIS ENGINE, STILL AT WORK, WAS THE FORE-RUNNER OF THE FAMOUS DE GLEHN TYPE. THE DRIVING AXLES ARE NOT COUPLED

two low-pressure cylinders inside, and two outside high-pressure cylinders, all driving one axle, as shown in Fig. 33.

This engine was subjected to severe trials, a record of which was presented by Mr. Sandiford before the Institution of Mechanical Engineers in 1886. The results were fairly good, but in practice it was found that the engine was no better than a two-cylinder simple locomotive, and it was soon after converted back to a simple engine.

There is also an American design of a balanced, compound locomotive which has been before the engineering world for several years, and is often referred to in the railway journals, though its principle appears to be confined to one engine, or perhaps two engines, built

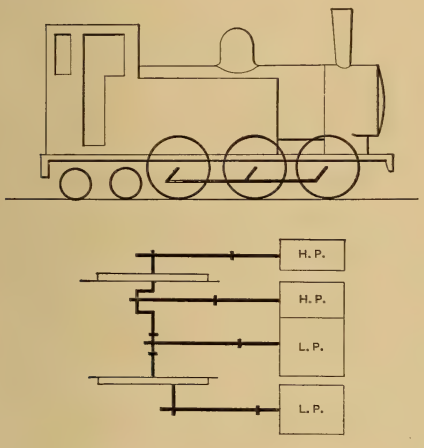


FIG. 34

for experimental purposes. This is what is known as the "Strong" balanced system. Mr. George S. Strong, of New York, developed this design especially for the purpose of scientifically balancing the engine, and it is said that the result in this respect is all that could be wished. The design is, as regards arrangement, the same as that of Mr. Sandiford's engine (Fig. 33).

Nothing more was done with this system, as far as the writer can authoritatively state, until Mr. Webb brought out his four-cylinder engines in 1897 on the London & North-Western Railway, though the writer believes that one, if not two, German engineers experimented with like systems in the interim. It is now common knowledge that Mr. Webb, in his first engine, "Black Prince,"—a trial companion to a four-

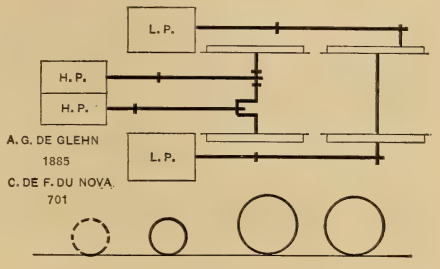


FIG. 36

cylinder simple engine, "Iron Duke," since renamed "Jubilee,"—used two blast pipes and a double chimney, the smoke box being divided horizontally, one blast pipe causing a draught through the lower tubes and the other through the upper tubes. These two engines,—for "Jubilee" was soon converted into a compound,—after very exhaustive trials, were pronounced satisfactory, and thirty-eight more of them were built. In 1902 twenty more, with larger boilers, and slightly varied dimensions, followed, and these sixty engines haul most of the best trains, though unfortunately, owing to the exigencies of traffic, so often with a "pilot" that it is hard to obtain a time estimate of their worth. These engines have the same cylinder arrangement as the preceding.

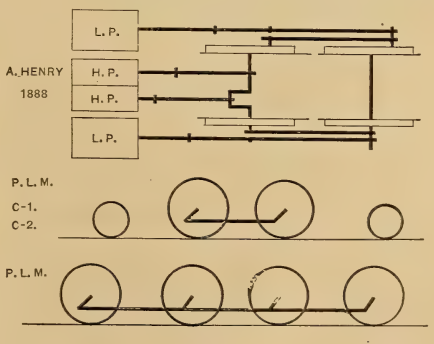


FIG. 37

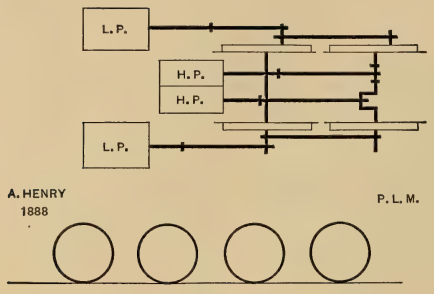


FIG. 38

The system has also been applied, recently, to the goods engines on the London & North-Western Railway, and a fairly large number of four-cylinder, eight-coupled engines, for mineral and heavy goods service, are now at work. The work of both these classes has often been commented upon, and the engines have been so well described in this magazine that it is unnecessary to say anything further about them here at this time. An engine has also been fitted according to this system on the Lancashire & Yorkshire Railway, but so far has not been duplicated.

On the Paris, Lyons & Mediterranean Railway, in France, there are in use about fifty eight-coupled goods engines with four cylinders abreast, all driving on to one axle. They were designed by C. Baudry, the present chief engineer of the line. In 1901 Karl Gölsdorf, locomotive engineer of the Austrian State Railways, who is well known for his two-cylinder system,—more than 1200 of these engines of various types being at work on the Austrian lines alone, and a number on Russian, German, American, Swedish and other railways,—found it necessary to design more powerful engines, and he, also adopted the four-cylinder arrangement under notice. At the time of writing, seventeen of these engines, of the "Atlantic" type, have been built for the Austrian State lines, with eminently satisfactory results.

The latest convert to the four-cylinder system with cylinders abreast is Mr. S. M. Vauclain, of the Baldwin Locomotive Works, of Philadelphia, the first engine of his type being the two-thousandth locomotive turned out (in 1902) from the Baldwin shops. This engine, No. 119, for the Plant system of railroads, was designed in conjunction with Mr. W. S. Symons, then locomotive engineer of the system, but since transferred to the Gulf, Colorado & Western Railroad. An essential feature of the Vauclain system is that the adjacent high and low-pressure cylinders shall drive cranks at 180°, so that their pistons are always moving in opposite directions, one set of high and low-pressure cylinders being arranged to drive at 90° to the other set; but this seems to be characteristic of the engines of the class under notice.

Engine No. 119 (see Fig. 33) is of the ten-wheeled type, and has an additional peculiarity in that the first of the three-coupled axles is the driving axle, instead of the middle one, as usual, an arrangement very rare in locomotive practice, though not unique. The engine is also fitted with a Vanderbilt corrugated firebox and with a Vanderbilt tender, besides comprising other novelties of less note. Although No. 119 has given good results in practice, no further engines of this type have been built. A curious, balanced, four-cylin-

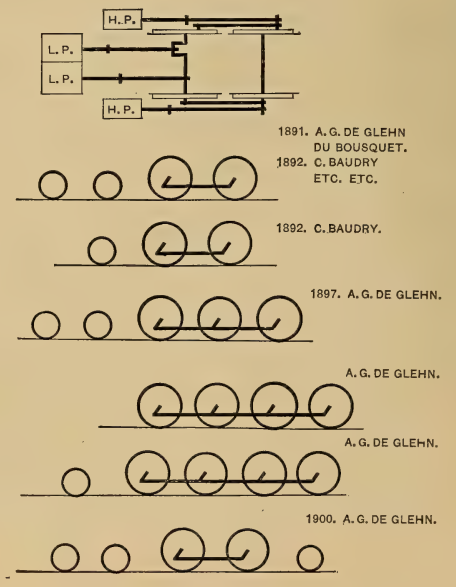


FIG. 39

FIG. 40.—ATLANTIC TYPE COMPOUND EXPRESS LOCOMOTIVE ON THE NORTHERN RAILWAY OF FRANCE. DE GLEHN SYSTEM

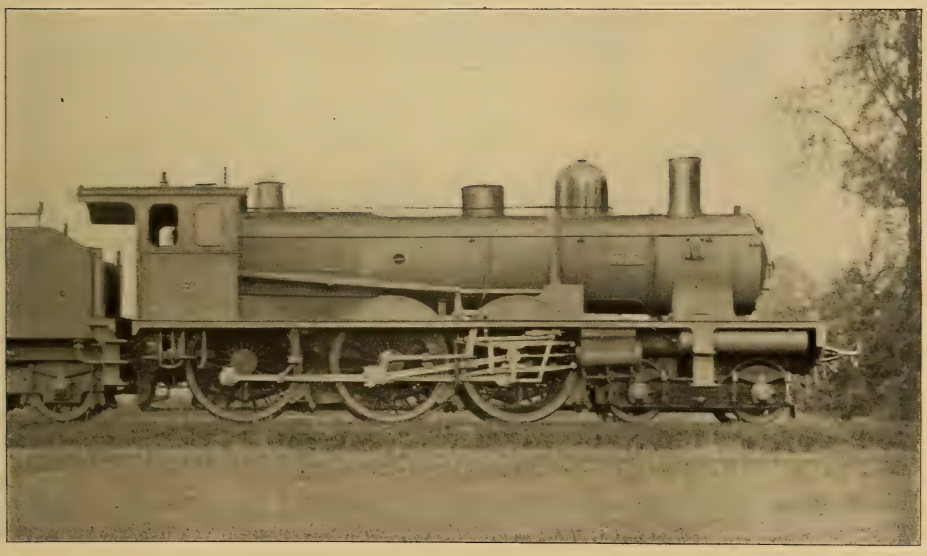


FIG. 41.—SIX-COUPLED BOGIE COMPOUND ENGINE, DE GLEHN SYSTEM, FOR THE ALSACE-LORRAINE RAILWAYS

der system now requires notice. In the Paris Exhibition of 1900 an express tank engine was exhibited (it also drew a tender, though a tank engine), designed to run cab first, belonging to the Italian Adriatic Railway (Fig. 34). This peculiar engine had the four cylinders abreast, and had—the writer has not been able to confirm this satisfactorily, —both high-pressure cylinders on one side of the centre line, and both low-pressure cylinders on the other side, as shown in the diagram.

2.—DIVIDED AND BALANCED COMPOUND LOCOMOTIVES

In the case of the balanced compounds just described, all cylinders drive on to one axle, and the whole power of the engine is transmitted through the one

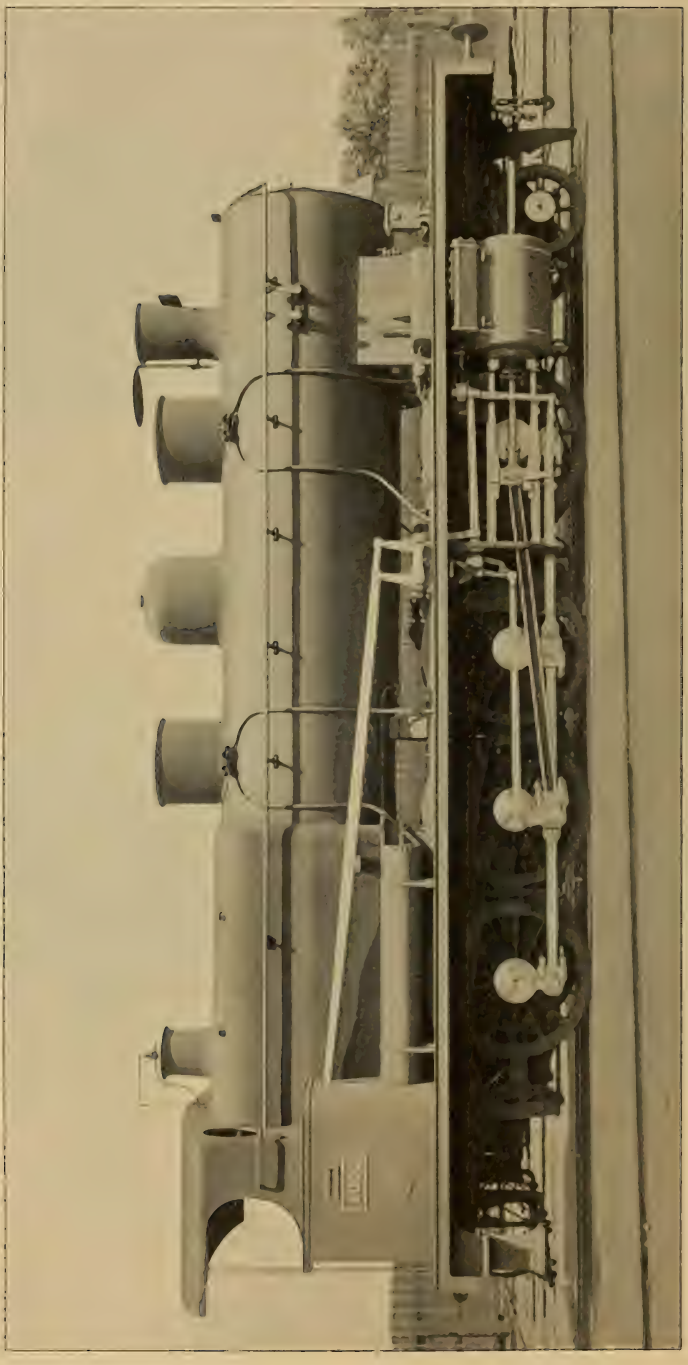


FIG. 13.—A CONSOLIDATION TYPE.—DE GLEHN SYSTEM.—ON THE CHEMIN DE FER DU MIDI, FRANCE

axle and only indirectly to the coupled axles. In what is known as the divided and balanced arrangement, however, the direct power is divided over two axles, the high-pressure cylinders driving one axle and the low-pressure cylinders driving another axle, the balancing being obtained by coupling the axles.

The divided arrangement is found in several of the locomotive types already described in other sections, notably, with uncoupled wheels, in the Webb three-cylinder compound engines, and the Swiss, Winterthur, Works, three-cylinder coupled compound engines. The first "divided" four-cylinder compound engine (and the only one requiring mention in this section), which is not "balanced," owing to the omission of the coupling-rods, is of note, as it is the first compound engine introduced by M. de Glehn, and, although never reproduced since, was the forerunner of the present highly satisfactory engines which have made de Glehn's name known all over the world.

This engine, shown in Figs. 35 and 36, was designed in 1885 for the Northern Railway of France. It had two high-pressure cylinders, inside, driving the front driving axle, and two outside low-pressure cylinders, set back on the frames, driving the rear pair of driving

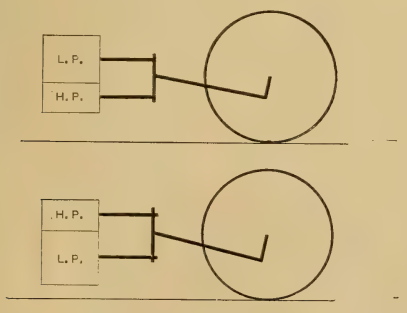


FIG. 44

wheels. The axles were not coupled, in which respect de Glehn followed Mr. Webb's practice, and it is worthy of note that, although in all subsequent engines coupling-rods have been employed, this engine is still at work with uncoupled wheels.

The following are the leading dimensions:—

H. P. cylinders (2) inside	13¼ in. in diameter
L. P. " (2) outside	18 " "
Stroke	24 "
Diameter of driving wheels	6 ft. 11 inches
Steam pressure	156 lbs. per sq. in.
Weight in working order	37 tons

The engine was shown at the Paris Exhibition of 1889. A few years ago a bogie was substituted for the single

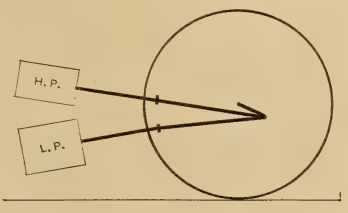


FIG. 43

leading axle. Otherwise the engine is still in its original condition, though, of course, it has long since been taken off first-class work.

Early in 1889, before M. de Glehn had done any further work in connection with his system of compounding as exemplified in this engine, No. 701, another leading engineer in France, M. Henry, locomotive engineer of the Paris, Lyons & Mediterranean Railway, entered the field with a compound system which developed for some years in advance of the de Glehn system, and which probably entitles M. Henry to far greater credit than is usually assigned to him.

Six engines were built according to this system,—of three distinct types, shown in Figs. 37, 38 and 39. In these engines coupling-rods were employed, in which respect M. Henry was certainly ahead of M. de Glehn, and, what is most important, a high steam pressure was used,—213 pounds instead of 156 pounds, as used in de Glehn's system; but the cylinder arrangements were very unusual, and although later engines for the P., L. & M. were built according to one of these arrangements, yet such dispositions of the cylinders have never since been repeated elsewhere, and even

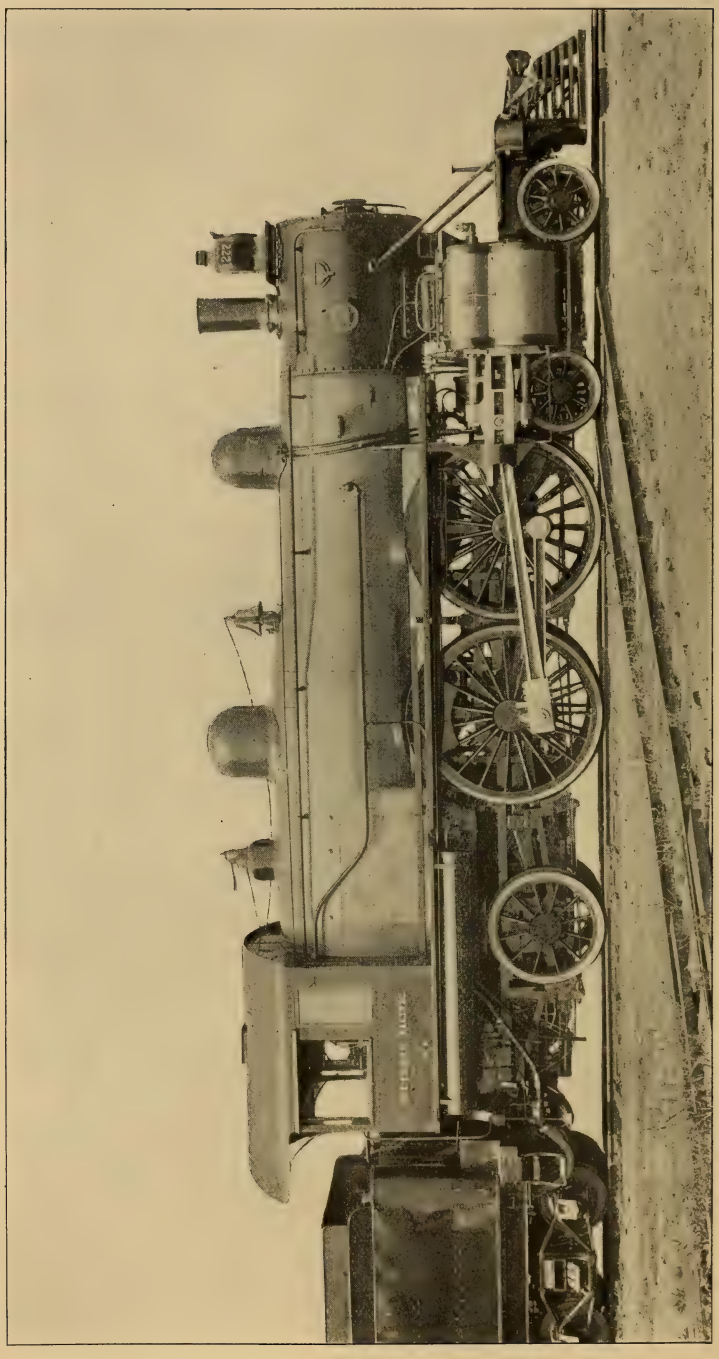


FIG. 45.—A VAUCLAIN COMPOUND "ATLANTIC" TYPE EXPRESS LOCOMOTIVE, BUILT FOR THE SOUTHERN PACIFIC RAILWAY BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA

the one arrangement thus inaugurated has been discontinued for some years.

The type designed for passenger use had the four cylinders abreast, but driving on to separate axles, the inside high-pressure cylinders driving the front coupled wheels, and the outside low-pressure cylinders driving, with long piston and connecting-rods, the rear coupled wheels. Two of these engines, Nos. *C—1* and *C—2*, were built, and one of them was exhibited at the Paris Exhibition of 1889, forming an interesting companion to de Glehn's engine above described.

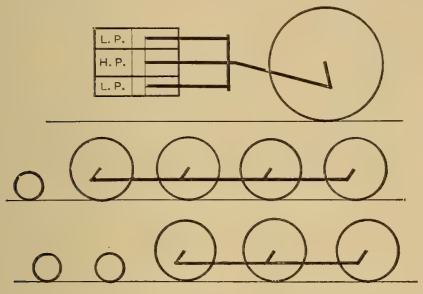


FIG. 46

The second type was an eight-coupled goods engine with the outside low pressure cylinders in the usual positions, driving the second axle, and with the inside high-pressure cylinders set back between the frames,—an absolutely unique arrangement,—and driving the third axle.

In the other two locomotives, also eight-coupled engines, all cylinders were under the smoke box; but the inside high-pressure cylinders were raised and inclined, and drove the second axle, while the outside low-pressure cylinders were fitted with long connecting-rods to drive the third axle. These engines, according to a statement made by M. Baudry, successor to M. Henry, proved very successful, owing, it is claimed, principally to the high steam pressure employed, and paved the way for an extensive adoption of the compound system for locomotives on the Paris, Lyons & Mediterranean Railway, even before M. de Glehn, together with his colleague, M. du Bousquet, on the Northern Railway, had evolved the design which has given such splendid results in more recent years.

Commencing in 1893 a number of other eight-coupled engines were built having the cylinders arranged according to the second types above described (Fig. 38). In 1892 was built the first of the thirty eight-coupled engines having all cylinders driving the second axle as described in the first section of the present article.

No further passenger engines similar to Nos. *C—1* and *C—2* were built; but in 1892 three engines were constructed, two of which, Nos. *C—11* and *C—12*, were of the four-coupled bogie type, and the third, four-coupled with a single leading axle, in which the low-pressure cylinders were inside and drove the front coupled axle, and the outside high-pressure cylinders were set back on the frames to drive the rear coupled axle

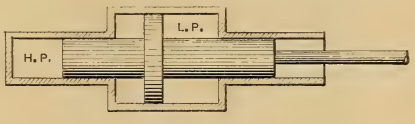


FIG. 47

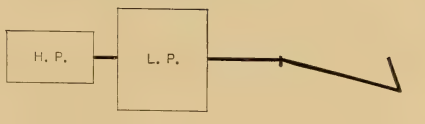


FIG. 48

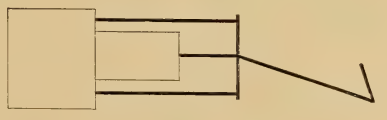


FIG. 49

thus conforming to the present cylinder arrangement in force on French railways (Fig. 39).

Commencing in 1894, M. Baudry built forty more four-coupled bogie engines of the same type as Nos. *C—11* and *C—12*, and since then further engines of various types on the same lines have been built as required, the Henry and the de Glehn systems having by

this time converged until the differences became those of detail design or in matters outside the present subject.

In October, 1898, M. Baudry stated before the Société des Ingénieurs Civils de France that he had 231 of these compound locomotives, as set forth above, in service on May 1 of that year, all of which had developed independently of M. de Glehn's work. It is not the intention of the writer to judge between de Glehn and Henry, and it is not the object of this paper to uphold the claims of one engineer against those of another, but to present in logical order the development of the compound principle on the P., L. & M. Railway at some length, as it is a subject neglected by most writers, in spite of the conspicuous success which has attended the introduction of compounding on French railways.

During the period covered by the P., L. & M. developments, however, M. de Glehn, and with him M. du Bousquet, had also been working, though it was not until 1891 that the type generally associated with the names of these engineers was properly instituted. Thus, in 1898 it was stated by M. Baudry that on the Northern Railway of France there were 135 compound engines, as follows:—

(1) No. 701, dated 1885
(2) 23 eight-coupled. tandem compound engines to be described in the tandem section
(3) No. 3,101, three-cylinder "Sauvage" compound already described
(4) 60 four-coupled bogie engines, dated between 1891 and 1898
(5) 50 six-coupled bogie engines, constructed in 1897 and 1898

Besides these, a large number of engines had been delivered to other French railways, and to German, Swiss and other foreign lines.

It is difficult to estimate the share taken by M. du Bousquet in the development of the system, for all along he has worked largely in conjunction with M. de Glehn. In all their engines after No. 701 the high-pressure cylinders were placed outside, driving the second coupled axle, the inside low-pressure cylinders driving the first coupled axle, and the development of the systems from ordinarily successful designs to the most successful designs at present in existence (as is almost universally admitted), are matters of detail which only a very lengthy description could make clear and for which space here is lacking.

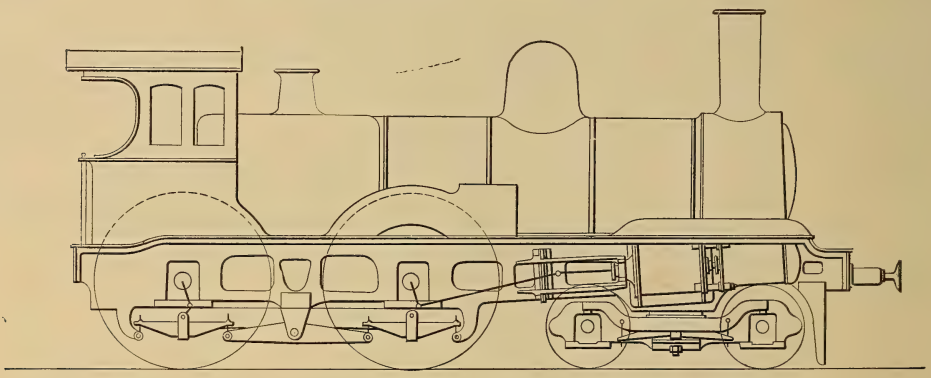


FIG. 50.—TANDEM COMPOUND LOCOMOTIVE ON THE SOUTH-WESTERN RAILWAY OF RUSSIA, DESIGNED BY M. M. DE GLEHN AND MALLET

Since 1898 the de Glehn system has been still further developed until we find more than 1500 of these engines in use in various countries. Further, one of the de Glehn engines, of the "Atlantic" type, is on order for the Great Western Railway in Great Britain, and will probably be delivered and at work before this article will appear.

The table on the next page, furnished by M. de Glehn, indicates the distribution of the de Glehn compound engines. The numbers in brackets are

FIG 51.—A BROOKS TANDEM COMPOUND LOCOMOTIVE, BUILT BY THE AMERICAN LOCOMOTIVE COMPANY FOR THE GREAT NORTHERN RAILWAY

the total of engines in each division, while the other numerals indicate the number built at the Alsatian Works.

M. de Glehn also informs the writer that he will shortly produce some eight-coupled tank engines, compounded on his system.

Fig. 40 illustrates one of the latest of the now famous "Atlantic" type engines for the Northern Railway of France. Fig. 41 illustrates a six-coupled de Glehn engine for the Alsace-Lorraine railways. Fig. 42 illustrates one of the new "Consolidation" engines, eight-coupled with pony truck, for the Chemin de Fer du Midi.

It has been mentioned that in 1895 a three-cylinder compound engine was built by the Swiss Locomotive Works at Winterthur for the St. Gothard Railway for competition with a four-cylinder engine. This latter was adopted as the standard; hence the St. Gothard Railway is a four-cylinder railway in a country consecrated to three-cylinder compound engines. It is necessary, however, to note that in the latest engines even the Jura-Simplon Railway, of Switzerland, is introducing the four-cylinder engines to cope with present-day loads. These four-cylinder engines are on the de Glehn system.

DISTRIBUTION OF DE GLEHN LOCOMOTIVES

	4-Coupled Bogie Type	Atlantic Type	6-Coupled Bogie Type	8-Coupled	8-Coupled with Leading Axle (Consol'd'n Type	Totals
France	121 (399)	40 (50)	81 (627)	(114)	4 (14)	246 (1204)
Germany	32 (44)	14 (15)	54 (140)	------	------	100 (199)
Spain	------	------	10 (40)	------	------	10 (40)
England	------	1 (1)	------	------	------	1 (1)
Other countries	(24)	------	(64)	------	------	(88)
	153 (467)	55 (66)	145 (871)	(114)	4 (14)	357 (1532)

3.—THE COMBINED CYLINDER SYSTEM

In 1882 one William Monk proposed that the compound principle should be applied to locomotives by disposing a high and a low-pressure cylinder at each side of the engine, the two connecting-rods working on to a single crank. The arrangement suggested is shown in Fig. 43. There is no record that this was ever carried out, but it represents in a very general way the embryo scheme of the Vauclain compound locomotive.

The Vauclain system consists in super-

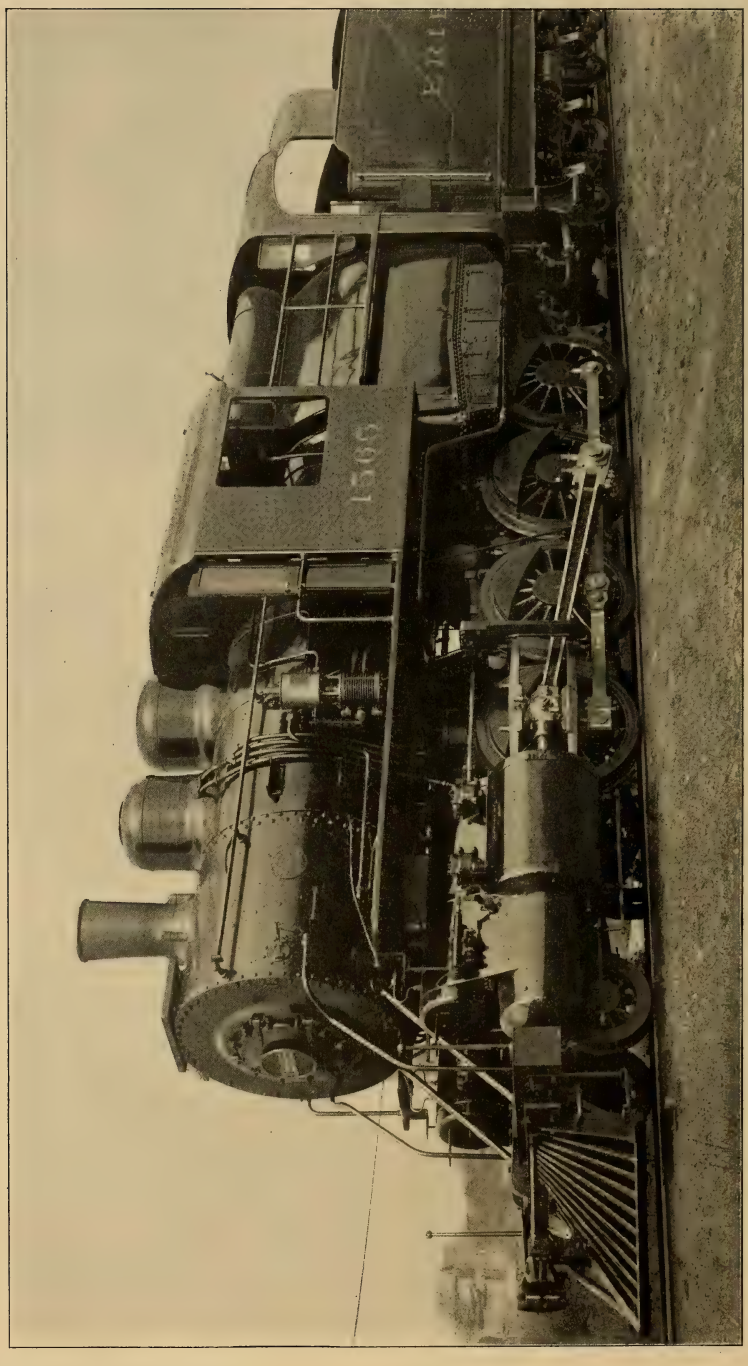


FIG. 52.—A TANDEM COMPOUND ERIE RAILWAY ENGINE BUILT BY THE AMERICAN LOCOMOTIVE COMPANY

posing a high and a low-pressure cylinder at each side of the engine, the two piston-rods in each case being attached to one large crosshead with a single connecting-rod, so that only one set of motions and a single valve (of the piston type) are required (see Fig. 44).

Anticipatory schemes have at one time and another been unearthed from the patent records and from technical journals, and it may be said that the Mallet-Lapage, double low-pressure cylinder system contains the germ of the idea; but in practice, the Vauclain system stands alone, for no other builders than the Baldwin Works turn out engines thus compounded, and yet the system has probably more representatives, widely scattered, than any other system.

The first engine on this system was an otherwise ordinary four-coupled bogie (American type) locomotive for the Baltimore & Ohio Railroad,—a railway historically famous as the scene of many locomotive triumphs and daring experimental innovations in the early railway days of America,—the engine being put in service in 1889. The cylinder ratio generally employed by Mr. Vauclain is about 3 : 1. Since its introduction the Vauclain system has been applied to thousands of locomotives of all types, and these engines have been supplied, outside the United States and other American states, to Russia, China, Japan, France, India, Italy, Egypt, Australia, and New Zealand. In the case of passenger engines, the high-pressure cylinders are usually placed above the low-pressure cylinders, while for freight or goods service, they are usually below.

Some of the Vauclain engines have wonderful records, and there are few engines better known in Great Britain than these, although that country does not possess a single representative of its own. These engines, of various types, have been illustrated many times in this magazine and other British and American journals, so that it is not necessary to speak of the system at length. Fig. 45 illustrates a good specimen engine, of the favourite "Atlantic" type, for the Southern Pacific Railroad. Its leading dimensions are:—

Cylinders, H. P.	15 inches diameter
" L. P.	25 " "
Stroke	25 inches
Driving wheels	7 feet diameter
Weight in working order	193,020 lbs.

This system has been applied to locomotives of practically every type now in use, and also to compressed air locomotives for mine and elevated railway service, and to rack, and combined rack and adhesion, locomotives, which will be described later.

In this section must also be included the annular cylinder system of Mr. F. W. Johnstone on the Mexican Central Railway. According to this arrangement, each high-pressure cylinder is placed within a large low-pressure cylinder, so that the latter is annular, as shown in Fig. 46. On the Mexican Central Railway there are very heavy grades, and powerful engines are needed. One of Mr. Johnstone's productions to provide adequate power has already been described in the December, 1903, number of this magazine. In that case he employed the tender to assist traction. His annular compounds represent a further attempt to keep his line up to date in the motive power department. The first annular cylinder engine was a Rogers locomotive of the Consolidation type, converted about 1890. The cylinders, after conversion, were

H. P. 14 inches diameter
L. P. 30¾ incdes diameter (equal to 24¼ inches)
Stroke, 24 inches
Cylinder ratio, 3:1

The low-pressure piston had two piston rods which were connected with the high-pressure piston rod to one crosshead. The tests were very satisfactory, and it was claimed for the engine,—No. 66,—that an all-round increase in economy of 20 per cent. was effected.

In 1891 ten engines of the ten-wheel type,—six-coupled with leading bogie,—and compounded according to this system, were ordered from the Rhode Island Locomotive Works. In these engines the cylinders were 14 and 29½ inches in diameter, the stroke being 24 inches. The steam pressure was 175 pounds; the driving wheels were 56 inches in diameter; and the weight of

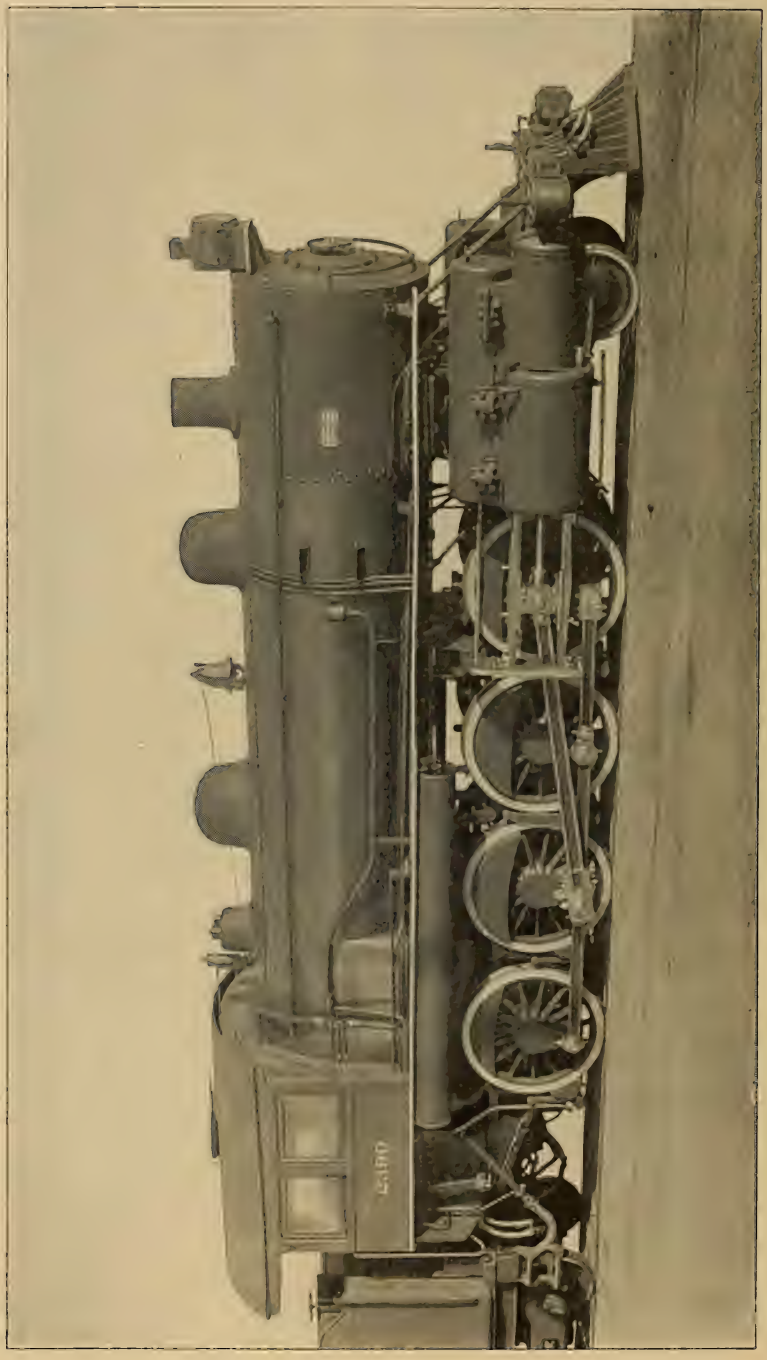


FIG. 53.—A TANDEM COMPOUND LOCOMOTIVE, BUILT BY THE SCHENECTADY WORKS OF THE AMERICAN LOCOMOTIVE COMPANY FOR THE NEW YORK CENTRAL RAILROAD

engine in working order was 66½ tons. One of these engines, —No. 146,— was tested for some time on the lines round Chicago before going home, and the results were held to be good. Some difficulty was experienced in this experimental use of the engine, for its dimensions would not permit of its going anywhere, and the authorities had to be careful where they sent it. In fact, these engines, and some special tank engines, to be described in Part IV., were very awkward machines to send on to other lines because of their dimensions. It is said that in going from the Rhode Island Works they would not pass through one of the tunnels on the Santa Fé road, and the cabs and various other parts had to be taken off before the journey could be continued. Three more of these compound engines, but of a special and unique design (to be described later), were afterwards built, making fourteen in all, and these represent the total number of annular compound locomotives on that or any other line.

FIG. 54.—A "PRAIRIE" TYPE TANDEM COMPOUND LOCOMOTIVE BUILT BY THE AMERICAN LOCOMOTIVE COMPANY FOR THE ATCHISON, TOPEKA & SANTA FE RAILROAD

4.—TANDEM COMPOUND LOCOMOTIVES

Tandem schemes for compounding locomotives were suggested long before other multi-cylinder systems came into use; but it is only in very recent years that tandem compound locomotives have been included in the successful list, though for many years experiments with tandem compound locomotives have been made.

An early idea for applying the compound principle to locomotives was to make the cylinders single-acting and to use the steam first in one cylinder and then in the other, or to use it first on one side of the piston on an annular surface, and then on the other side on the full area. These arrangements have not, so far as the writer is aware, been put into practice, though they are not unknown in stationary engines. The first suggestion of a tandem compound locomotive was of this character, though it was never practically utilised.

In 1860 an American, one Ebenezer Kemp, suggested the arrangement shown in Fig. 47. The high-pressure piston was to be of trunk form having the low-pressure piston attached, and the combined pistons worked in connected cylinders, or in one large cylinder having two diameters, a valve admitting steam first to the high-pressure cylinder to force the piston one way, and then allowing it to pass to the low-pressure cylinder to force the piston back. There is no record that an engine on this system was ever built.

In 1868 another American engineer, Mr. H. O. Perry, seems to have fitted

FIG. 55.—A TEN-COUPLED COMPOUND LOCOMOTIVE ON THE ATCHISON, TOPEKA & SANTA FE RAILROAD BUILT BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA

an Erie Railroad engine as a four-cylinder tandem compound with double-acting cylinders, end to end, as shown in Fig. 48; but this, like so many of the tandem compounds that followed, was a failure, and there are very few particulars of it available.

In 1879 M. Mallet concerned himself with multi-cylinder arrangements, his two-cylinder system having by this time obtained a firm footing, and, in his book on his "Compound Systems," describes several tandem compound schemes for locomotives, of which one, with the cylinders separated, may be considered as the first suggestion of a tandem compound locomotive as now carried out.

To M. du Bousquet, of the Northern Railway of France, is due the first design of a tandem compound locomotive of which a number of representatives were built. In 1882 this engineer converted three outside-cylinder, eight-coupled goods engines by fitting at each side a high and a low-pressure cylinder, end to end, as in Fig. 49, the arrangement being what is known as the "Woolf" system, that is, the cylinders were combined and steam passed directly from one cylinder to the other, controlled by a single slide-valve, and there were at each side two low-pressure piston rods, passing outside the high-pressure cylinder, and connected with the high-pressure piston rod to a single cross-head. In 1890, extended trials of these engines having proved satisfactory, twenty new engines of the same type were built, and, until superseded by the more modern engines, these were used on the best work.

But other engineers had also been busy, and during this period several experimental locomotives were built which require notice, though none of them were ever duplicated, and most of them were soon reconverted to simple engines. In 1883 an engine of the Boston & Albany Railroad was fitted as a tandem locomotive. This engine failed to give satisfaction; but it is stated that the designer, Mr. Dunbar, was not able to attend the trials and experiments through illness, and it is probable that it might not have been such a failure as it is generally considered to have been had he been able to look after things. After seven months' trial the engine was reconverted to a simple engine.

About 1886 three tandem experiments were made on British railways. A North British engine,—No. 224, the engine which, years before, had gone down in the historic and disastrous Tay Bridge catastrophe, but was fished up again and put back into service little the

worse for its immersion,—was fitted according to Mr. Nisbet's patent with inside tandem cylinders 13 and 20 inches by 24 inches. Experiments were made, but the results were not satisfactory, or, at any rate, not better than with the engine in its original condition, and so it was reconverted to a simple engine.

On the Great Western Railway experiments in tandem compounding were made by Mr. Dean, the lately retired locomotive superintendent. There were two engines, one, the writer believes, for the narrow and one for the broad gauge; but neither survived, and there is little information available concerning them. In one engine, the arrangement usually termed the Woolf system, used by M. du Bousquet on the Northern Railway of France (Fig. 49), was adopted, but with the cylinders inside, the low-pressure cylinder being in front and having two piston rods between which the high-pressure cylinder was located, the three piston rods being connected to one cross-head. The other engine was arranged as usual with tandem cylinders, one piston rod carrying both high-pressure and low-pressure pistons, as in Fig. 48. These engines, though not absolute failures, did not give results better than a two-cylinder simple engine would give, and so they, also, soon ceased to be tandem compound engines.

According to an arrangement proposed by M. Mallet in 1879, a high and a low-pressure cylinder were to be placed end to end between the frames of the engine, about centrally to its length, and the piston rods were to work from the cylinders in opposite directions, the connecting-rods being connected backwards to cranks on the two driving axles, the whole scheme being somewhat similar to two steeple engines laid horizontally, end to end. This suggestion was never carried out; but M. Mallet's designs for a tandem compound engine on orthodox lines, on the general plan outlined in Fig. 48, were later adopted.

The du Bousquet "Woolf" system has not been adopted elsewhere than on the Northern Railway of France, but in 1901 fifteen tandem compound tank engines (ten-wheelers) were built at the Northern Railway works at La Chapelle for the Ceinture Railway. These were designed by M. du Bousquet, but it is not known whether they were "Woolf" or ordinary tandem engines.

In 1891 MM. de Glehn and Mallet appeared on the scene as designers of tandem compound engines. In that year an engine was built at the Belfort Works of the Société Alsacienne for the South-Western Railway of Russia, designed by M. de Glehn on lines laid down by MM. Mallet and de Borodine. As will be seen from the diagram, Fig. 50, in this engine the adjacent cylinders are separated, although the two pistons at each side are on the same piston rod. This is the arrangement set forth in M. Mallet's suggested scheme of 1879, already referred to, and in this respect differs from most of the tandem engines so far described. This engine was never reproduced, but proved to be the forerunner of a very numerous class of engines of larger dimensions which are now standard types on Russian railways.

Hungary is also a large user of similar tandem compound engines of various types, and it is curious to note that although everywhere else the tandem compound engine has not been introduced successfully, or to any extent (with the exception of the du Bousquet engines on the Northern Railway of France), until recent years, these two countries, Russia and Hungary, have for a long period systematically adopted the system for a majority of their new engines, and probably even to-day there are more of them in these two countries, often considered as only half civilised, than in all the rest of the world.

In 1899 twenty heavy goods tandem engines of the Consolidation type were designed and built at the Grafenstaden Works of the Société Alsacienne for the Moscow-Vindau-Rybinsk Railway, of Russia, which may be said to represent up-to-date practice in tandem compounding as used on the Continent of Europe.

Somewhat similar engines have been built by Messrs. Krauss & Co., of

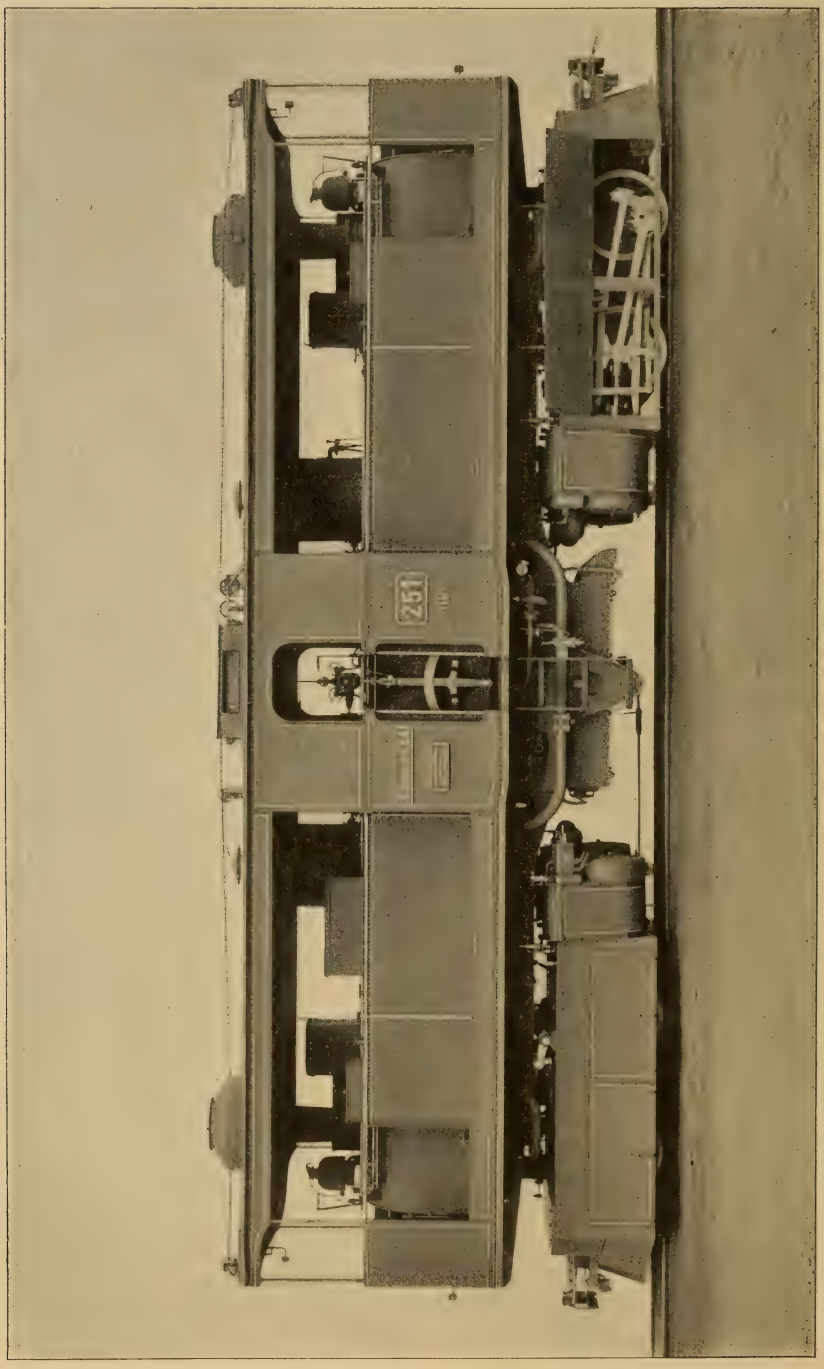


FIG. 56.—A COMPOUND FAIRLIE TYPE LOCOMOTIVE ON THE SAXONY STATE RAILWAY, BUILT BY THE SAECHSISCHE MASCHINENFABRIK, CHEMNITZ, GERMANY

Munich, for the Bavarian State and the Palatinate railways of Germany. These were compounded according to Sondermann's system, and there were four of them, of the Consolidation type; but the engines did not show any noticeable advantage beyond their simple confrères, and were soon after converted to simple engines.

There now remains to be described briefly the developments of the tandem compound locomotive as a successful machine during recent years in the United States. The first really satisfactory engines appear to be two, built by the Brooks Locomotive Company for the Great Northern Railroad, one of which is shown in Fig. 51. They are of the Consolidation type, and the particular engine illustrated was exhibited at the Chicago Exposition of 1893. Both engines are still running.

Fig. 52 shows one of the latest examples of tandem compounding, this engine, with four others, having been built at the Cooke Works of the American Locomotive Company in 1902 for the Erie Railroad. So far, these engines are giving highly satisfactory results. Other engines built recently by the same company, but at the Schenectady Works, for the New York Central and the Northern Pacific Railroads, have like satisfactory records. Twenty-seven engines are represented by these two types.

Another engine of similar type was delivered from the Pittsburgh Works of the same company in 1901 to the Baltimore & Ohio Railroad. Fig. 53 illustrates one of the Schenectady engines for the New York Central & Hudson River Railroad.

This brief review of the tandem compound engines of the United States leaves out one railway. To Mr. John Player, superintendent of motive power of the Atchison, Topeka & Santa Fé Railroad, the successful development of the tandem compound locomotive is principally due, and it is on this road that by far the larger number of American tandem compounds are to be found. The first of these appeared in 1898, and was of the Consolidation type. The engine had 15 and 25 by 28-inch cylinders, in ratio of 1 to 2.78, wheels 57 inches in diameter, steam pressure 180 pounds per square inch. The engine was designed to be practically identical with a non-compound engine with 21-inch cylinders.

From a published record of tests with the engine the following facts are extracted:—One driver, expert all round, was set to drive alternately the compound and an almost identical simple engine with 21 × 28-inch cylinders. Four double trips were worked with the simple engine and six double trips with the compound engine. The comparison, when results were carefully tabulated, gave a saving in favour of the compound of:—

Water used per ton of train	13.4	per cent.
Coal " " "	18	"
Coal per gallon of water	4.4	"
Water evaporated per lb. of coal	4.9	"

The trial trains weighed about 800 tons, worked over stiff gradients. Since that date other engines have been built, and there are now in use forty engines of the Consolidation type, three of the Decapod type (ten coupled wheels with a leading pony truck), and two of the Prairie type (six-coupled with a pair of leading and a pair of trailing wheels). They are all intended for freight service, and the Consolidation and Decapod engines are used on the mountain divisions of the Santa Fé line. Mr. G. R. Henderson, the present locomotive chief of that railway, writes to the author with reference to them as follows:—

"The general results obtained from these engines have been very good. One difficulty with these tandems, however, is that as the packing of the piston rod between the high and low-pressure cylinders is located so that it cannot be seen, it is difficult to find out when it leaks and when it is tight. Another difficulty is that it is extremely hard to get at the low-pressure piston packing, as it takes something like twelve to twenty hours to make a complete inspection of this packing."

It is such difficulties as these which go against the tandem system. When a satisfactory means is provided for overcoming them, the adoption of tan-

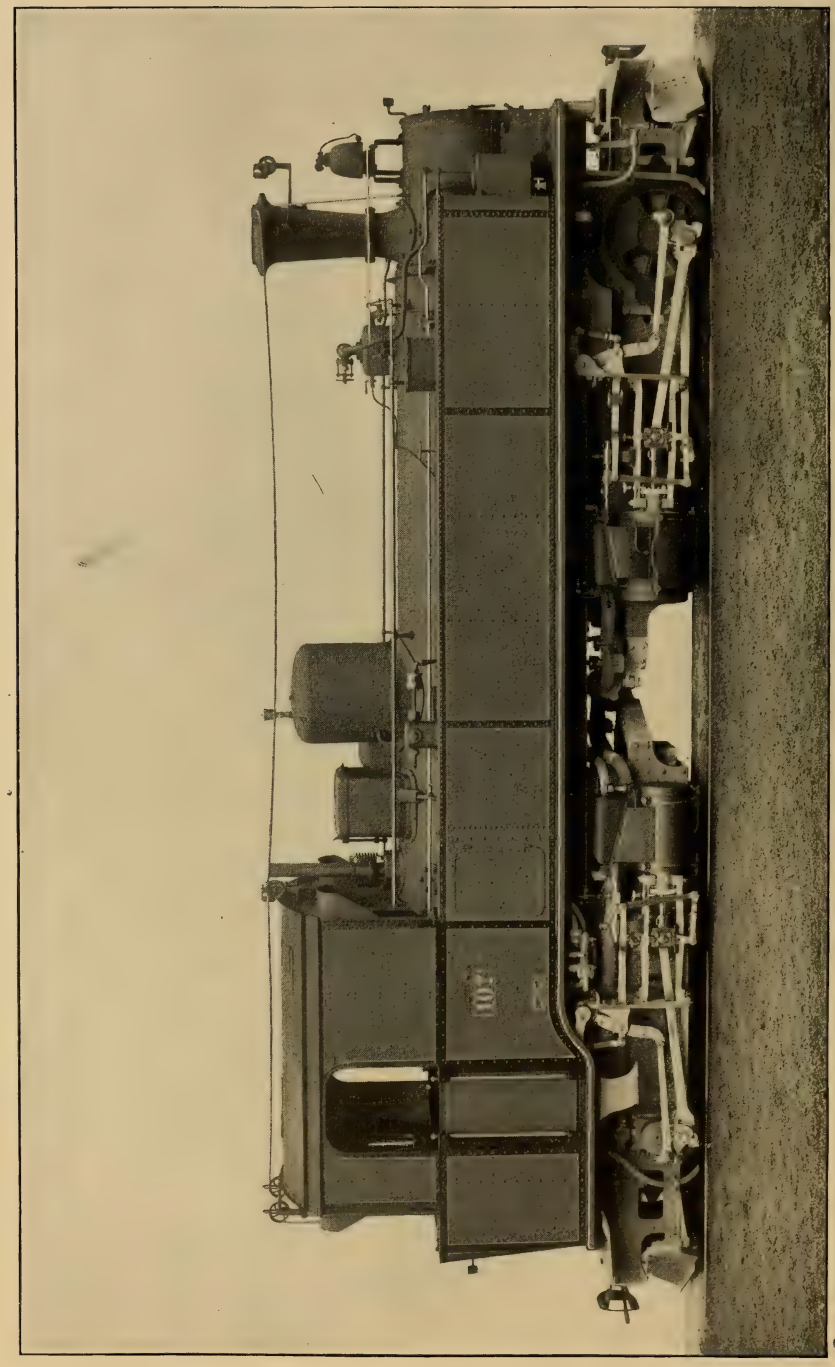


FIG. 57.—A MEYER-LINDNER ARTICULATED LOCOMOTIVE, NARROW GAUGE, BUILT BY THE SAECHSISCHE MASCHINENFABRIK, AT CHEMNITZ, FOR THE SAXON STATE RAILWAY. THE FRONT BOGIE CARRIES THE LOW-PRESSURE AND THE REAR BOGIE THE HIGH-PRESSURE CYLINDERS.

dem cylinders will probably become more general, and there is evidence already that tandem compound locomotives will be largely multiplied in Amer-

FIG. 58

ica. Such engines are now included in the regular building types of both the principal locomotive building firms of America, the Baldwin Works and the American Locomotive Company, the latter an amalgamation of most of the remaining important locomotive works out by using one pair of cylinders for high-pressure steam and the other pair, of larger diameter, for the second expansion.

The Fairlie type of engine,—double boiler as well as double cylinders,—has not been adopted to any great extent as a compound, as the single-boiler type has almost superseded it. But representative engines even of the compound Fairlie type are not wanting. One of them is shown in Fig. 56. This is the only class of which the writer is aware, though there are probably others, designed for steam tramway or light railway work on the State lines of Saxony. This engine is covered in above and be-

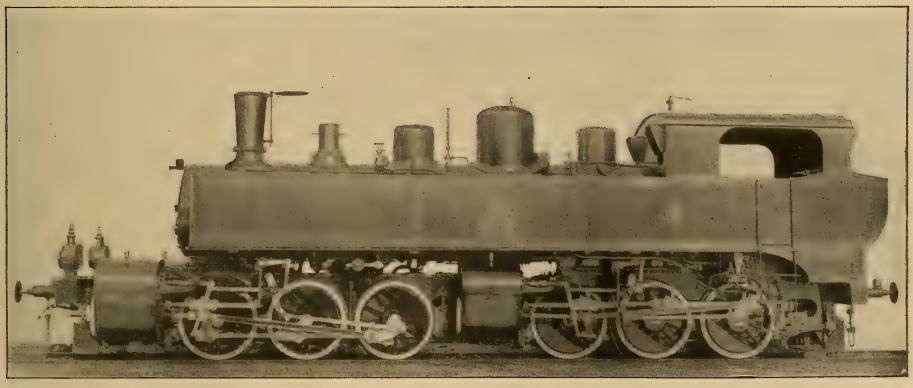


FIG. 59.—A MALLET COMPOUND ARTICULATED TANK LOCOMOTIVE, BUILT BY J. A. MAFFEI, OF MUNICH, GERMANY, FOR THE ST. GOTHARD RAILWAY.

in the United States. Both of these firms have been employed in building the Player engines referred to, and some engines have also been built at the Santa Fé shops, at Topeka, Kansas. Fig. 54 shows one of the Atchison, Topeka & Santa Fé Railroad engines of the Prairie type as built by the American Locomotive Company. Fig. 55 shows one of the Decapod engines on the same line, built by the Baldwin Works.

5.—DOUBLE AND ARTICULATED ENGINES

The double and articulated non-compound engines have already been described, and the application of the compound principle to them has been carried low, and, therefore, presents rather a strange appearance. The Sächsische Maschinenfabrik, formerly Richard Hartmann & Co., Ltd., of Chemnitz, Germany, are the builders.

The true "articulated" engine with a single boiler has been compounded according to two systems, and these locomotives are to be found in very large numbers on Continental, and especially mountain, lines, most of the locomotive building firms having had a share in building them.

In "simple" practice most of the articulated engines have all the cylinders placed close together between the two sets of coupled wheels, and in the compound engines of the Meyer type, com-

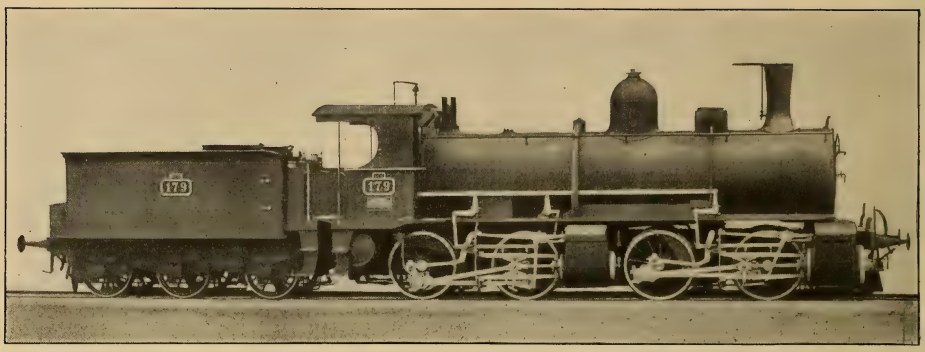


FIG. 60.—A MALLET COMPOUND ARTICULATED TENDER ENGINE BUILT FOR THE SWISS CENTRAL RAILWAY, BY THE SWISS LOCOMOTIVE WORKS, WINTERTHUR

pounded according to what is known as the Lindner system, the cylinders are also thus arranged. Fig. 57 illustrates a good recent specimen of an engine of this character, built also by the above works in 1899 for the Saxon State lines.

The Mallet system, which differs from the foregoing, as regards cylinder arrangement, is by far the more general. In this the cylinders all drive the same way. It was first suggested in 1879, and was patented in condition for carrying into practice in 1884.

There is no need to describe the system further, as it is so generally known, and probably most people think of M. Mallet principally as the originator of these engines, and somewhat neglect his important work in producing the first really practicable two-cylinder compound engines (see Fig. 58). They are in use on lines of various gauges, and of very small and very large dimensions. Most of them are tank engines, for they are principally used for short and special service; but there is also a fair number of tender engines similarly constructed.

Fig. 59 illustrates a large, six-axle tank engine built by the firm of J. A. Maffei, of Munich, in 1890, for the St. Gothard Railway. The weight in working order is about 84 tons. Fig. 60 illustrates a tender engine on this system built by the Swiss Locomotive Works for the Central Swiss Railway.

As evidence of the widespread use of these engines, it may be noted that, according to M. de Glehn (Société Alsacienne), his firm has built seventy-five of these locomotives, mostly narrow-gauge tank engines, but some of them, for Russia, with a separate tender. These also include about twenty large tender engines (standard gauge) for the Prussian and Baden State railways. The narrow-gauge engines were for France, Germany, Switzerland. Luxemburg, Spain, and Russia; the Swiss Locomotive Works have supplied them to the Central Railway of Switzerland, the French District Railways, and others; and the firm of J. A. Maffei have also supplied them in considerable numbers.

A new locomotive now being built by the American Locomotive Company for the Baltimore & Ohio Railroad represents the first introduction of the Mallet duplex compound system into the United States. Some of the Mallet engines already in existence are of very large dimensions, but the B. & O. engine will be, without doubt, the "biggest engine in the world." It is mounted on twelve wheels, in two sets, the front set being arranged in a bogie frame and driven by the low-pressure cylinders, and the rear set being driven by the high-pressure cylinders according to the usual Mallet practice. The wheels are 56 inches in diameter, with coupled wheel bases of 10 feet and a total wheel base of 30 feet 6 inches. The cylinders are 20 and 32 inches in diameter, with a stroke of 32 inches, and the weight in working order of the engine (without tender) will be 285,000

pounds. The Walschaert valve gear will be used,—a distinct innovation for American practice. The engine is intended for heavy mountain service, and adds one more to the already lengthy list of locomotive novelties which appear in the locomotive history of the Baltimore & Ohio Railroad.

Part IV., the concluding one of this series, to appear in the March number, will include those four-cylinder locomotives which could not properly be placed in any of the preceding sections, and also those locomotives which have more than four cylinders.

THE COMMERCIAL VALUE OF INDIAN COAL

SUGGESTIONS FOR DEVELOPING IT

By Myles Brown, M. Inst. M. E.

THERE is a wide field in India for improvements which would lead to the more satisfactory use of Indian coal and help to dispel the prejudice against it which now exists. The producers of the coal are, in some respects, to blame for its evil reputation. The quality of the coal varies widely even in the same seam, and many producers never consider the quality of the coal dispatched to buyers or that of competitive coal in the same market. Large quantities have often been exported which were not worth the freight charges.

Indian coal in general is bituminous in character, with dull and bright zones, the former producing the larger percentage of ash. It is deficient in fixed carbon, runs above the average in volatile matter, and is high in ash. Regarding ash, Assain coal is excepted. A considerable number of analyses have been given in various journals and in papers read before learned societies, but the general fault with such analyses is that "the sampling is not above suspicion." The majority of the samples having been supplied by interested parties, a great difference is found between the practical and the laboratory results.

To obtain a thoroughy reliable basis for determiningthe correct absolute heating power of a first-grade Indian coal, the writer personally took the samples and made the analyses and tests. The sample was obtained by cutting a groove through the whole section of the seam; thus the whole seam is truly represented. An approximate quantitative analysis of the first-grade coal showed 51.52 per cent. of fixed carbon, 37.51 per cent. of volatile matter, and 10.97 per cent. ash. The coal yielded 62.49 per cent. of coke of good quality, silvery gray in colour, with only 0.35 per cent. of sulphur. The absolute calorific power was 12,251 B. T. U., and the evaporative power was 12.67 pounds of water per pound of coal. The greatest difference obtained in the results of a number of tests was only 0.15 per cent.

It may be honestly asserted that the Indian collieries can put on the export market a coal of a guaranteed absolute heating power equal to 12,250 British thermal units. The same may be said regarding the home market; but there are, of course, quantities of lower-grade coal which can be profitably (to buyers and sellers) consumed only near the point of production. Low-grade coal which can be profitably consumed within a certain radius of the collieries might not be worth the freight incurred, if the transport exceeded a certain limit.

Indian coal at present competes at certain points with British, Australian and Japanese coals. A large number of tests from samples, taken from various British coals ready to export, gave the average absolute heating power

as 13,480 British thermal units. Regarding Japan's coal, some authorities fix the ratio of heating power as 5 to 6, compared with Welsh coal. Thus taking the absolute heating power of Welsh coal as 14,500 B. T. U., Japanese coal would produce 12,083 B. T. U. From analyses there does not seem to be any great difference in the qualities of Australian, Japanese and first-grade Indian coal, and there seems to be no valid reason why first-grade Indian coal should not compete favourably at many points with the others.

The cost of any coal is a variable quantity, depending upon the cost of production, handling, transporting and storing. The absolute heating value of any coal has always a standard value. Taking the case of Japanese and Indian coal on the Singapore market, the value to the consumer of each should be much the same; yet Japanese coal commands the better price. There can be only one explanation for this, namely, that the Indian coal put on this market has been of a low grade and far below the standard which should always be adhered to in export coal. There is a splendid field for any Indian company who will standardise its coal, and supply only the best qualities for export; or to any place where foreign coals compete. In the past, many markets have been closed against Indian coal, because of the indifference of the producers.

Regarding the important question of the combustion of Indian coal, consumers are themselves often to blame for not utilising the whole of the available heating power. Furnaces which have been consuming Welsh coal containing 10 to 17 per cent. of volatile matter, are not suitable for Indian coal, containing 30 to 40 per cent. of volatile matter. Indian coal requires a strong draught and an adequate supply of air to ensure proper consumption of the volatile matter. The chief of an important engineering firm in Calcutta asserts that it is almost impossible to burn Indian coal properly without some system of forced or induced draught.

A well-known fact is that the consumers of Indian coal do not get the same percentage of efficiency from the coal they consume as the consumers in Great Britain do from British coal. From a large number of British tests it was found that the boiler efficiency, the percentage of British thermal units utilised in evaporation, was from 60 to 75 per cent. The efficiency of Indian boilers is well below these figures, a considerable number giving an efficiency of only about 50 per cent. A special test which was scarcely free from pecuniary interest gave an efficiency with first-grade Indian coal of 62 per cent.

The Indian mining industry is increasing in importance. At present there are no Indian mining institutes where scientific matters affecting the industry could be thoroughly discussed. The present mining association is chiefly mercantile, and does not take up the scientific side of the industry. However, the present association could do an important work,—a work which would result in further prosperity to the industry,—by correct determinations of the relative value of Indian coal.

An uninterested committee should obtain samples of coal truly representing the qualities put on the market.

Samples of the coal should be taken from different seams, such seams to be carefully named or numbered. The samples obtained should be burned under the same conditions in the same boiler plant, and the practical results noted. From the evaporation the relative value of each coal could be determined.

A number of tests should also be made to determine the most suitable draught and style of furnace adapted to the consumption of Indian coal. Samples should also be tested in the calorimeter to determine the absolute heating power of each coal.

With more care in the selection of the coal for the market, and with its favourable position in the eastern seas, the Indian coal mining industry should have a prosperous future.

THE INDIVIDUAL APPLICATION OF ELECTRIC MOTORS TO MACHINERY

WITH RULES FOR DETERMINING THE SIZE OF MOTORS

By William Cooper

THE technical press has been overrun with descriptions of the individual application of electric motors, and volumes have been written on the subject, describing various forms of application. There is, however, throughout all this matter a very great lack of data, or information in regard to the actual power used by the different machines to which the motors have been applied, or to which it is contemplated applying them. A great mass of data has been given; but these, in most cases, have been assumed Very little of the information is the result of actual operation. It is usually given in the form of the motor being of a certain horse-power, as applied to a certain machine; but it is not reduced to any basis on which further calculations can be made.

As a result of all this there have been many applications of motors in which the motor has been out of all proportion to the work to be performed,—in some cases unnecessarily powerful, and in a great many cases too small. The last fault is especially pronounced in the so-called variable-speed motors as applied to machine shop tools. Quite a demand has sprung up for electrically-driven machine tools in the last two or three years, and a great many machine tools have been built with motors attached to drive them. In many cases these motors were mere toys, as compared to the work which they were expected to perform.

The favourite method of obtaining variable speeds is the field method of regulation. But a desire to keep the motor within a certain size, so that it would not be abnormally large in proportion to the machine to which it was to be attached, has led in many instances to the use of motors that are entirely too small when they are expected to yield a considerable range of speeds by field regulation. This condition of affairs is a handicap to the use of electric motors for variable-speed work, as these failures are so numerous that they have brought this branch of the business into disrepute, and it is only the persistence of the demand for this class of machinery that keeps the business alive. The great difficulty and impossibility almost of operating a variable-speed motor on any one fixed and constant voltage through a range that is applicable to machine shop tools has led one electrical firm, prominent in the field of individual motor-drive, to absolutely refuse to fill orders of this kind.

The writer was called not long ago to inspect a lathe in the factory of a prominent machine tool manufacturer, which was equipped with a variable-speed motor. This motor was intended to have a range of speeds of four to one, these speeds being obtained by shunt field regulation, the motor operating on one fixed voltage. The motor behaved very badly, and the tool manufacturers were at a loss to account for its poor working. A test showed that the motor would not do the maximum work that it would be called upon to do even when running on its full field strength, and when running at its point of weakest field it sparked badly while the machine was doing no work. These are the cases that give motor-driving in general a black eye.

The inability of motor manufacturers to furnish a motor with a comparatively

wide range of speed and operating on a fixed and constant voltage has led machine tool manufacturers to devise various forms of mechanical speed-changing devices. These devices fill the gap and make it possible to equip a machine tool with an electric motor which can be operated on a fixed voltage and yet have power enough to properly operate the tool.

The advent of the high-speed tool steels has also made the question of motor-drive in machine tool practice more difficult. It has also shown to the machine tool manufacturers that their tools have not the necessary pulling power to do the work that it is possible to do with these steels. The machines themselves in a great many instances are shown to be weak. With the best tool steel obtainable, prior to the introduction of the so-called high-speed steels, a 24-inch engine lathe with one tool could be made to use only three or four horse-power, while with some of the new steels the same machine will readily absorb three or four times this amount.

These are the points to which both the machinery manufacturers and the motor manufacturers must give strict attention, if the business of individual application of motors is to advance as the qualifications of an electric motor for this work warrant. It behooves the machinery builders to guard against sending out machines equipped with motors that will not fulfill the conditions perfectly. It is far better to burden the machine with a complex set of change gears than to equip it with a variable-speed motor that is not able to meet all the demands which will be made upon it. The manufacturers of electric motors have, of course, to take the butt end of all the blame. So long as the motor is not capable of working the machine to its limit, the machine stands blameless.

The question of how much of the total range of speed variation of any given machine should be taken care of by the motor is a matter of opinion. The machine manufacturer naturally asks the motor manufacturer what range he can furnish. The motor manufacturer, anxious to make as good a showing as possible for his motor, and perhaps not knowing the conditions to be fulfilled, guarantees a wider range than the motor can cover and fulfill its functions properly. In this he is at fault. The greater the number of motors that are put out under these conditions, the slower the business will progress, and it is certainly poor business policy to furnish apparatus of this kind.

This question of equipping machines with motors that are unable to perform the work which they are called upon to do brings the motor-drive into disrepute in still another way. The motors which are thus overloaded burn out, and the machines to which they are attached are thrown out of service. This leads to the belief that motors in general are poor, weak things, and makes the ordinary purchaser prejudiced against the apparatus as a class. It not only prejudices the purchaser, but it apparently affects the minds of people who are in a position to know, and should know, that electric motors, as constructed by the best manufacturers, are not toys or playthings, but machines to be thoroughly depended upon when properly designed for the work which they are called upon to perform. This is evidenced by the behaviour of street car motors. Certainly no other class of machinery could be subjected to the same abuse and work under as adverse conditions as a street car motor and have anything like the life that this kind of motor has.

In a recent issue of one of the technical journals, in an editorial comment on the advisability of building the electric motor as an integral part of the machine to which it is applied, the following statement was made:—

"Unfortunately for the progress of electric machine-tool driving, it is, in the present state of the art, bad design to make an electric motor an integral part of a machine tool. This condition exists because of the still primitive state of the electric motor, which makes it quite necessary to be able to quickly replace burnt-out armatures, etc. If the armature is mounted on a shaft which

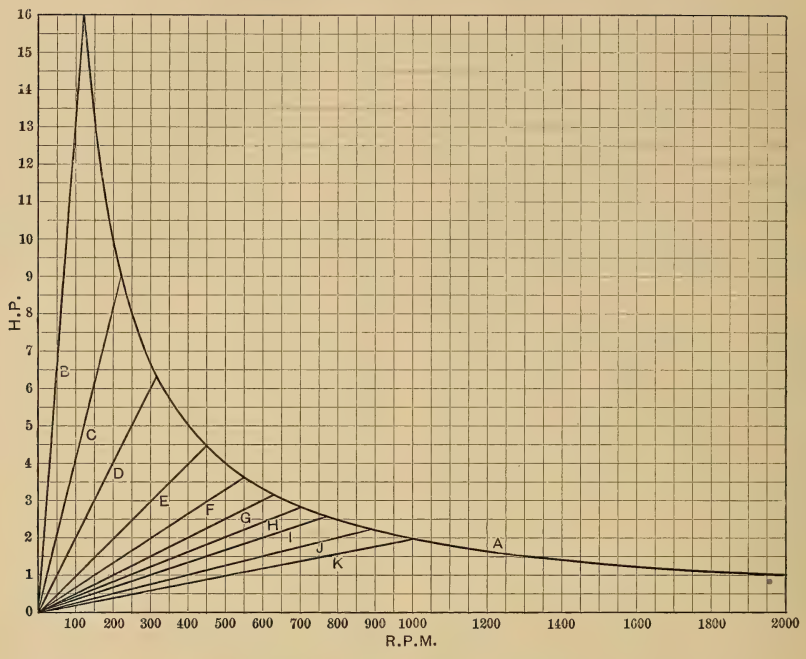
forms a part of the machine, such as a lathe spindle, for instance, it is special, and its replacement is a matter of days or weeks, depending on the distance from the factory, their promptness, etc. But, if a standard motor is used, the replacement of a burnt-out armature, or of the entire motor, is a simple matter. If one make of motor is not available, another generally can be readily substituted. It is true that one of the first attempts at driving lathes with electric motors was made by building the motor in the headstock and mounting the armature on a quill which corresponds to the cone pulley, but this design was a failure. A stroll through the machine shop of an electric concern, well known for their efforts along these lines, will discover a number of engine lathes, originally built with the motors in the headstock, but now equipped with standard motors mounted on the field rings of the old motors. They found that their lathes were lying idle too much of the time, because of repairs to the motors, and so abandoned the idea. When some better means of insulating the windings of motors are discovered than is now known, it may be feasible to make them part of the machine tools; but it emphatically is not so now, except, perhaps, in the case of some small tools like grinders or drills."

The statement that such motors were replaced is a fact, but the reason assigned is entirely erroneous. The writer has personal knowledge of the matter referred to, and can say positively that the reason these motors were replaced was because they were not powerful enough to do the work that the machine in which they were built was capable of doing. The construction, of necessity, required that the motor should have a maximum speed the same as the maximum speed at which the spindle of the lathe would be operated, and a minimum speed that would be called for by the slowest speed on the lathe. These limiting speeds would be, on a 24 or 30-inch lathe, a minimum of about 40 or 50 revolutions per minute, and a maximum of 250 to 300 revolutions per minute. The construction also limits the cubical contents of the motor. It is practically impossible to build into the headstock of a 24-inch lathe a motor of sufficient power to properly operate the machine. The inability of these motors to properly perform the work which they are called upon to do was made especially evident upon the introduction of the high-speed steels, and it was for this reason, and this reason alone, that the machines were altered.

Statements like the one quoted, appearing as leaders in prominent technical journals, do an injustice to the manufacturers of electric motors. It must be admitted, however, that some electric motors are placed upon the market which are not by any means perfection in workmanship and material. The same conditions exist in the manufacture of electric apparatus that exist in the manufacture of any class of machinery. There is always some apparatus of inferior grade on the market. However, it must be said that the modern electric motor, as built by the best manufacturers, is as reliable as any part of any machine to which it may be connected.

One more illustration of this eternal unfitness of things:—The writer recently received an invitation to inspect, in company with several others, who are directly or indirectly interested in such matters, a new motor-driven lathe. This lathe was built by one of the leading machine tool builders for an electrical manufacturing company, and, of course, was equipped with one of their motors. From what was said about the outfit, one expected to see quite a wonderful creation. What was seen was this:—

A 20-inch swing lathe with about a 10-foot bed. A motor of the semi-enclosed type mounted upon, and a little to the rear of, the centre line of the headstock, connected by a chain drive to an intermediate shaft, upon which was mounted a pinion that meshed into the main gearing in the headstock. The gearing was so arranged that by the manipulation of two levers, which operated friction clutches, four different speeds could be obtained, having a ratio



ELECTRIC MOTOR HORSE-POWER CURVE, MULTIPLE VOLTAGE AND FIELD REGULATION

of 3.2, that is, the second speed was 3.2 times as great as the first; the third speed was 3.2 times as great as the second, and so on. The gearing and clutches were all enclosed in a neat and compact manner, and all parts seemed to be of liberal proportions and in keeping with the balance of the machine tool. In fact, the lathe was a fine example of its type and, together with the method of mounting the motor, made a very mechanical and neat appearance. The motor was said to be a variable-speed motor of 3 horse-power, having a speed variation of two to one by field regulation. The controller for the motor also contained armature resistance, the intention evidently being to increase the speed range of the motor to about three to one by the use of this resistance.

The first thing noted was that the motor sparked viciously when running at its maximum speed, taking full load current, and no work being done other than rotating the piece in the lathe and overcoming the friction of the machine. With a good operating cut on a piece of steel, the current was about four times the full load current, and the motor was threatened with destruction. There can be but one result in this case, as in many others like it,—the absolute failure of the motor to perform its functions, and the ultimate replacing of it by a larger one. In this particular case, a motor which would be capable of giving at least 10 horse-power at any point of its range would be none too powerful for this tool.

The important point to be determined in the individual application of electric motors is the maximum amount of power required to operate the machine and the conditions which will require this power. If the maximum power required be coincident with the maximum speed, and the amount of power decreases with the speed, a motor having field regulation is ill-adapted to the work of furnishing different speeds. If the power required is nearly constant, or if it decreases as the speed increases, this method of regulation is much more applicable.

Having determined upon the condition under which the maximum power will be required, the next point is to

determine the amount of power. This should be very carefully considered, as the successful operation of the machine will depend in a great measure upon it. In equipping machine tools with motors, if the kind of work which the machine is to perform is known, the amount of power required can be very closely determined.

In the case of an ordinary engine lathe, which will, without doubt, be used to turn steel shafting to some extent at least, the power required will be almost exactly proportional to the pounds of metal removed. This is true irrespective of the speeds or feeds used, while for machines to operate on cast iron, the amount of power required varies with the feed used. In working steel, the amount of power required is about one horse-power per cubic inch of metal removed per minute. This is very nearly correct for all ordinary working conditions, except in the case of a milling machine using a very fine feed.

In machining cast iron the power required varies from two-tenths to one horse-power per cubic inch of metal removed per minute, depending upon the feed per tool. In some exceptional cases it may run even higher than this. A 20-inch swing engine lathe of modern design can easily take a cut one-fourth of an inch deep with one-sixteenth of an inch feed, and, using high-speed cutting steel, a cutting speed of 60 to 80 feet a minute can be easily maintained. This will call for from 11 to 15 horse-power. It is evident that the lathe above mentioned, which was equipped with a 3 horse-power motor, will hardly meet the requirements, especially when running on a weakened field.

Knowing the amount of power required to operate any given machine, and the conditions of the requirements, the next point is the selection of a suitable motor. If a constant-speed motor is to be used, the selection is a very simple matter. If a variable-speed motor is to be used, it may be quite different. In the first case it is only necessary to select a motor which will operate at a speed applicable to the machine; while in the second case there is not only one speed to consider, but several speeds, depending upon the range through which the motor is to operate.

If the behaviour of a motor under various methods of speed regulation is fully understood, the selection of a variable-speed motor can be more intelligently made. There are certain rules governing the power of an electric motor, when operating at different speeds, depending upon the method of regulation. It is well known that the power of a direct-current electric motor decreases in inverse ratio as the increase of speed when the speed is increased by field regulation. It is also well known that the power of a direct-current motor increases in a direct ratio as the increase of speed when its speed is increased by increasing the volts impressed upon its armature. These rules are inflexible, if the same margins be maintained in the motor. To illustrate:—

Assume that a given motor, when operating on its normal voltage, has a speed of 600 revolutions per minute. If the speed of this motor be increased to 1200 revolutions, the load which it will carry with the same margin will be one-half its normal load. If its speed be decreased to 300 revolutions by decreasing the volts impressed upon its armature one-half, its power will be one-half the normal with the same margin.

However, the limiting condition in the two cases is not the same. In the case of its speed being increased by field weakening, the limiting condition will be its tendency to spark at the commutator. In the case of its speed being decreased by lessening the impressed volts, its limiting condition will be heating of the armature. If the motor normally had a margin of 100 per cent. in both heating and sparking, or, in other words, was capable of carrying double its rated load, it would carry its normal load under the above conditions. It is, therefore, necessary, if it is desired to increase the speed of a motor 100 per cent. by field weakening, to have 100 per cent. margin for sparking at normal speed, if the motor is to carry normal load at the increased speed. The same

is true in regard to heating, if the speed is to be decreased by lessening the impressed volts.

These rules are graphically presented in the accompanying diagram. The change in speed and horse-power by change in field strength is represented by the curve *A*, while the change in speed and horse-power by change of voltage is represented by the lines *B*, *C*, *D*, etc. From this diagram we can determine the minimum size motor that will be required for any given case, using either shunt field regulation entirely, or combining shunt field regulation and multi-voltage, or multi-voltage entirely.

Suppose, for instance, that a given machine tool requires 1 horse-power to operate it under all varying conditions of service, and it is required to have a speed range of four to one. We can get this in three ways:—One by using entire field regulation, which will require a motor of 4 horse-power at 500 revolutions per minute with normal field strength; or, if two voltages are available,—one of which is double the other, —a 2 horse-power can be used running at 1000 revolutions at normal field strength, or one-fourth as large as the motor giving this range by field control entirely; or this motor can be run at 2000 revolutions by increasing the voltage.

The horse-power of this motor, due to reduction in speed by reduction in voltage, will decrease along the line *K* in the diagram, so that at 500 revolutions it will give 1 H. P., and also give 1 H. P. at 2000 revolutions by weakening its field, following line *A*. It is seen from the curve that with two voltages, —one of which is double the other,—in combination with weakening the field, the range of speed of four to one is the maximum that can be obtained from a motor which will be worked to its full capacity at both the minimum and maximum speeds.

If any greater range than this is required under these conditions, a larger motor must be used. For instance, suppose that a speed range of five to one be required, and the variation obtainable by changing voltages is only two to one. Assume, as before, that the maximum speed is 2000 revolutions per minute; the minimum speed will be 400 revolutions. Now, as 400 and 800 revolutions will be the speed variation by changes in voltages, these voltages being in the ratio of two to one (say, 110 and 220 volts), a motor will be required to develop 2½ H. P. at 800 revolutions on full field; this is indicated by the point at which the curve *A* crosses the ordinate of 800 revolutions. The horse-power of this motor will decrease, as that of all other motors, directly in proportion to its speed by reduction in voltage. It will, therefore, be 1¼ H. P. at 400 revolutions, being in this case slightly in excess of the power required at the slowest speed. The motor, however, in this case would be equivalent of a 3.1 H. P. at 1000 revolutions, or more than 50 per cent. larger than a motor to do the same work with a speed range of four to one.

A motor will be six times too large when operating at six times its speed, the speed being increased by an increase in voltage; in order to get the same range by shunt field regulation, the motor would require to be thirty-six times the size it would be if operating only at the one maximum speed. This, in itself, is sufficient proof of the superiority of the system of getting variable speeds by variable voltages over the system of shunt field regulation exclusively.

From this it follows that a motor whose speed is to be varied by change in voltage, field excitation remaining constant, will be directly proportional in size to the change in speed; while a motor whose speed is to be varied by change of field excitation will be in size as the square of the change in speed.

In conclusion, the writer would indicate a few rules to be used in determining relative sizes of motors for constant horse-power application.

First.—The total range of speed, using both variable voltage and field regulation, will be as the square of the range of voltages.

Second.—The change of horse-power

will be directly proportional to change of voltage on armature, field being constant.

Third.—The change of horse-power by change of field strength will be inversely proportional to change in speed, the voltage on the armature remaining constant.

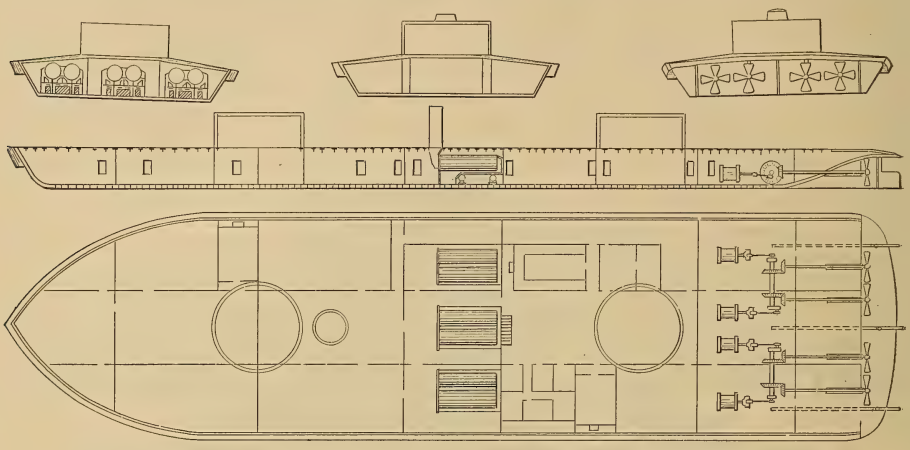
Fourth.—The relative size of motor, as referred to the maximum speed, will be directly proportional to its speed variation when using variable voltages.

Fifth.—The relative size of motor, as referred to the maximum speed, will be as the square of the speed variation when using field regulation.

Current Topics

When we read of triple-screw cruisers of the present day as among the best examples of the modern shipbuilder's art, it may be interesting to recall that with respect to these, as well as many other things and events, history certainly seems to persistently repeat itself. The plaint is familiar that, unfortunately for the glory of the inventor of the present age, the ancients invented so many of the things which periodically bob up as new and wonderful. In the matter of ships with more than one or two propelling screws we need, however, not go more than about forty years back to find that during the American Civil War, in the sixties, a number of gunboats were built for the United States Navy which were equipped with four propellers on four distinct shafts. They were named *Winnebago*, *Chickasaw*, *Milwaukee*, and *Kickapoo*, and were designed and constructed by the late Captain James B. Eads, of Mississippi River bridge fame, under direct contract with the United States Navy Department. Plans and specifications of these floating batteries were never in the Navy Department, and probably never existed in complete form anywhere, the vessels being built as they advanced, tentatively, according to Captain Eads' ideas. The work was superintended by Naval Constructor Edward Hart, long since dead, and by Chief Engineer James W. King, U. S. N., retired. The batteries carried a thin armour, had a very small draught of water, full model, and very little speed. They were flat-bottomed, and of the following dimensions:—Length, 230 feet; beam, 56 feet; displacement, 970 tons; draught, from 6 to 7 feet. Each had two Ericsson turrets containing two 11-inch Dahlgren guns. The vessels were intended to co-operate with the army against towns on the Western rivers, but were not completed in time for any important

service. Their machinery lay-out is indicated in the diagram reproduced on this page from a blue print kindly supplied by Rear-Admiral C. W. Rae, U. S. N. The vessels, which, by the way, are claimed to have been the first ones to be propelled by screws on any drive the three propellers. The shafts were about 4 inches in diameter,—in some places more. The vessel is mentioned as having had a speed of eleven knots. Her cost was stated as $2,000,000. Possibly still more interesting multi-propeller ships of an earlier gen-



PLAN AND SECTIONS OF UNITED STATES QUADRUPLE-PROPELLER RIVER BATTERIES

Western American river, had bateau sterns, and their limited draught of water required the four screws in order to obtain the necessary propelling surface. All the detail drawings of the boats were made under the inspection and supervision of Chief Engineer King. This was true as well of the interior fittings, including the turrets and gun mountings. It would appear that very little interest was taken in the batteries by the technical bureaus of the United States Navy Department at the time, and little was expected from them, so that no further particulars of them are available.

Besides these vessels mention should be made of a triple-screw floating battery, the *Mississippi*, built at about the same time at New Orleans for the Confederate States Navy. This would seem to have been a rather more formidable craft than those mentioned in the preceding paragraph,—a sea-going vessel of several thousand tons, 270 feet length, and 60 feet beam, with four engines to eration were a number of Russian circular ironclads which had six shafts, and the Russian imperial yacht *Livadia*, which had three. To these, however, we shall revert more in detail in an early issue.

Undoubtedly the most noteworthy recent development in electric railway engineering has been the advent of the alternating-current, single-phase railway motor, which opens up interesting possibilities in the field of electric traction. The superiority of the alternating current as a system of transmission and distribution has been fully established. Its application to railway service has, however, until recently, been limited to the transmission of current from a central power station to distributing substations, in which it is transformed from alternating to direct by means of the rotary converter. This limitation has been due to the fact that no alternating-current motor has been available which possessed proper characteristics for the operation of a car under the usual con-

ditions of urban service. It is essential that a railway motor for general service shall be capable of operating at variable speeds, and that this speed variation shall be under almost exact control. These requirements have been successfully met by the direct-current, series-wound motor, especially when used in combination with the modern system of series-parallel control. As, however, this system of control involves the use of resistance in series with the motors, speed control is obtained only at a sacrifice of economy. It possesses, in fact, but two "running" points of full efficiency, namely, with motors in parallel, and with motors in series, with resistance cut out in both cases. At all other points energy is wasted in the resistance. This condition limits continuous operation to two running speeds, as it is impracticable to equip a car with resistance of sufficient capacity for continuous service.

With the alternating system a more economical control is possible, as speed variation is obtained by a change in voltage, which does not involve the use of the series resistance. This system possesses the further advantage that it permits economical operation at any speed within the capacity of the motors. In general, the new system, as developed by the Westinghouse Company, includes a transmission of current from a central power station at any desirable voltage. Static transformers of standard type reduce the potential to that selected for the trolley line. These transformers may be located at convenient points, and sub-station attendants will not be needed, thus greatly reducing the cost of operation. As the system is single-phase, a single circuit only is required. The advantages of the present direct-current system in this respect are, therefore, retained, while the possibility of high potentials will greatly lessen the cost of line construction. A transformer on the car again reduces the voltage, thus making it possible to wind the motors for a low potential. In this way the problems of insulation are greatly simplified, and the dangers of short-circuit and motor burn-out are reduced to a minimum, while the presence of a transformer on the car between the motors and the line practically eliminates danger to the motors from lightning or other static disturbances. An experimental car, equipped after the plan here indicated, has been in operation for some time near the Westinghouse Company's works. It has been pretty generally known that the projected electric road from Baltimore to Washington is to be equipped with this system, and it had been expected that the road would be in operation by the autumn of 1903. Various complications have delayed the work temporarily, but it will be carried to completion ere long. But for this delay the new system would by this time have been for several months in everyday use.

The production of electricity direct from coal without intermediary processes has been the dream of inventors for many years past; but energy and ingenuity in this field seem to have been largely misspent. Certainly no progress worth mentioning has been made in the past ten or twelve years even though periodically rose-coloured accounts have appeared of some new way of attaining the desired end. What progress there has been in the generation and use of electric energy has come along conventional lines,—through improvement in the steam engine, the development of the steam turbine and the gas engine, and the perfecting of electric lamps and introduction of new and more economical lighting systems, such as that, for example, represented by the Cooper-Hewitt mercury vapour lamp. The gas engine to-day comes nearer the commercially successful direct producer of electricity from fuel than anything else, and no one has been quicker to realise this and to try to provide for the requirements which will ultimately spring from this fact than the builder of large steam engines. Hence we find the large gas engine in a number of cases as an auxiliary output of the steam engine shop, with fair

promise of becoming the chief end of the business in the near future; and where the gas engine has not thus been taken up, the steam turbine has taken its place, with the result that this once despised rotary motor is now on the market in a number of different designs and has orders to its credit of hundreds of thousands of horse-power.

In the United States one company alone recently had on its books orders calling for over 300,000 horse-power. Of what is being done in Great Britain in steam turbine installation, a recent summary of the more important work showed that in London the Chelsea power station of the Underground Electric Railway Company,—now building,—will be supplied with eight turbines of 7500 horse power each, or 60,000 horse-power in all. For the generating station of the Metropolitan Railway Company turbines of an aggregate of 14,000 horse-power are being installed, while Brighton Corporation and Liverpool Corporation have on order plant of this type to the extent of 7500 horse-power and 4000 horse-power, respectively. The North Metropolitan Power Company are building a station at Brimstown which will supply energy for driving a great system of tramways in Middlesex and Hertfordshire, and there three turbines, aggregating 4000 horse-power, will be used. The first steam-turbine electric plant of any magnitude in Scotland is now about to be installed for the Clyde Valley Electric Power Company, the total being 16,000 horse-power. Harrowgate town council are putting down a 1000 horse-power turbine, and the Yorkshire Electric Power Company have on order plant of a similar type with an output of 6000 horse-power. The power is given in round numbers, but approximately the total just enumerated, neglecting the smaller installations, is no less than 112,000 horse-power. The bulk of these machines are of the Parsons type, built by the British Westinghouse Company; but some are Curtis turbines, made by the British Thompson-Houston Company, and a few of the Parsons model are coming from the shops of the Brush Electrical Company. On the Continent of Europe turbine sentiment, too, is found strongly developed, and French and German and Swiss builders are all helping to swell the horse-power figures to a most commanding total.

Electric fans of the warm-weather order have other uses than the familiar one of stirring up the air in times of summer heat and thus affording relief to perspiring humanity. As a means of preventing the frosting of display windows of shops in winter time there is nothing simpler or more effective than the air blast of such a fan directed against the glass. The philosophy of the thing is plain. The evaporative effect of the air current simply prevents condensation of moisture upon the window, and affords relief from an annoyance which generally is sought, but only imperfectly attained, through various other awkward means. Fan makers might find it worth while to exploit this field of usefulness for their wares, which, with the end of the heated term, are generally considered as cumbersome stock to be carried over to the next summer.

At length, after two years of anxious waiting and hoping, the crisis in German industrial values which began in the spring of 1901 is definitely past, and a general recovery has not only begun, but has progressed so far as to have all the outward indications of permanence. So says Consul-General Frank H. Mason in a recent report, in which he gives a table showing the market values of certain standard German industrial stocks in April, 1900, when German prosperity was at its height; in September, 1901, when the depth of depression had been reached; on the last day of 1902, when recovery had definitely begun; and late in November, 1903, when the effects of returning activity had be-

come manifest in the values of industrial securities. The twenty-two companies figuring in this table, in various branches of production, may be taken as representative of the electrical manufacture and the mining and metal industries of Germany. The table shows that while not one of them has recovered,—in respect to the open-market value of its shares,—the high-pitched prosperity of the early months of 1900, all have recovered in an important degree from the depressed prices of September, 1901, and each one now rules from 10 to 50 points higher than it did at the close of 1902. This recovery has largely taken place during the past two months, and may be ascribed to two or three primary causes. The first of these is the fact that the negotiations between Germany and the several European governments over the commercial treaties based on the new German tariff are understood to be progressing favourably. Another important element has been the fact that several of the leading electrical manufacturing companies,—which have recently combined to avoid competition,—have secured some important contracts for lighting and power plants, street railway installations, etc., in foreign countries, notably Mexico and South America. At a recent meeting of representatives from all the electrical manufacturing companies, it was found that they were, almost without exception, running on full time, and with orders booked that will keep them occupied for several months to come. Many of these orders have been taken at what might seem low prices; but the German electrical industry is enormously developed, is equipped with up-to-date machinery, has an abundant supply of cheap, docile, skilled labour and can turn out electrical machinery, cables, and all that class of work at minimum cost.

Finally, there is behind the present recovery the natural fact that the crisis of panic, doubt, and suspicion has run its course, the rotten, dishonestly managed concerns have gone to the wall, the guilty directors are mostly in prison, the solid, honestly managed companies that weathered the storm have re-enlisted public confidence, and the time has come for normal recovery. German exports in most lines are steadily increasing, and their far-reaching merchant marine, backed by the enterprise, the thorough, skillful methods of their merchants, salesmen, and capitalists in remote countries, combine to secure for German manufacturing exporters a constantly widening market for their products. As a people they understand the ethics of foreign commerce; they educate their young men for it, and make a systematic study of the wants and tastes of alien peoples and the best methods of supplying them.

In reviewing engineering progress during the year 1903, the London *Engineer* mentioned recently as one of the most noteworthy departures of that period the extended use of the steam turbine for marine propulsion. The circumstances, it was remarked, closely resemble those under which the compound engine and surface condenser were introduced nearly forty years ago. Then, serious objections were raised to the innovation; grave doubts were entertained; anticipations of evil prevailed. But progress went on. In the same way the steam turbine has grown day by day in favour, and from finding with difficulty a place on torpedo destroyers, it is now in use in Channel steamers, and before the year has passed it may be found in Atlantic liners of the largest class, to say nothing of warships. It is believed, however, that the marine steam turbine of the future will be very different in form from that fitted, say, to the Channel steamer, the *Queen*, recently shown in these pages. The Parsons type of engine, *The Engineer* goes on to say, occupies a great deal of floor space, and very little height. It takes up as much deck room, so to speak, as a piston engine of the same power. This in a man-of-war would be a decided advantage, but for a merchant ship it is

not. In such a vessel it is better to save floor space than height,—that is to say, to shorten the engine room, and for this reason it is desirable that a turbine in which the flow is radial instead of parallel should be adopted. There is, besides, the advantage that by using turbine wheels of larger diameter, the necessary high circumferential speed can be got, although the speed of rotation is moderate, and in this way we can dispense with toy propellers, which are not at all suitable for the rough-and-tumble life of ocean steamers, finding their way in and out of crowded docks and rivers. It is true that the parallel-flow type dispenses with a thrust block, the steam pressure on the vane wheels taking its place. But this, after all, is not a very serious consideration; and even if it were, it is by no means impossible to construct the engine in such a way that steam could still take the place of metal. The enormous quantity of condensing water required is always available at sea, and there is nothing very wild in the prophecy that with the next decade the piston marine engine will have given way to the turbine. As it is, more than one great firm of marine engine builders are laying their plans for the manufacture of the turbine marine engine on a very large scale indeed.

HERE it may be interesting to note that the efforts which the United States Navy Department has been making during the past year to have marine steam turbines tried on a large scale are promising early results. The special board, appointed by the Department a few months ago, to examine into the adaptability of steam turbines for warships, has made a report to the effect that the demonstrated efficiency of this form of motor is such as to justify the provision of turbine installations for two scout ships of about 3000 tons each, which it is proposed to ask Congress to authorise in the naval appropriation bill. The present plan of the Navy Department with reference to the use of turbines in the scout ships is to ask Congress to make immediately available the special appropriation of $25,000 requested by Admiral Rae, chief of the Bureau of Steam Engineering, for experiments with turbines, and also an allotment of the estimated cost of the two scout ships sufficient to cover their engines and boilers. Without special provision neither of these sums would be available until July 1 next, but the Department desires that the investigation now on foot shall proceed as rapidly as possible. The speed to be specified for the scout ships will probably be 23 knots, and this will require, roughly, 10,000 horse-power for each vessel. The installation of turbines in vessels of this size will be a most important step in naval construction, and its bearing upon the future of the merchant marine as well will be a matter of great interest.

A COMPLIMENT has been paid to Britain's great Indian dependency by naming one of the largest of the new battleships the *Hindustan*. The vessel was launched six weeks ago at the Clydebank establishment of Messrs. John Brown & Co., Ltd., and belongs to the *King Edward VII.* class, having a displacement of 16,350 tons. The important feature wherein the vessels of this type differ from their predecessors is that they mount, in addition to four 12-inch guns, four guns of 9.2-inch calibre, in secondary casemates at the corners of the citadel, with ten 6-inch guns in a box battery within the citadel. The armour extends from 5 feet below the water-line right up to the upper deck, the successive strakes from the water-line being 9 inches, 8 inches, and 7 inches in thickness. The First Lord of the Admiralty, who was present at the launch, seemed to suggest that the *Hindustan* marked only one step in the gradual development of the modern warship, for which Sir William White has been so largely responsible. Although he did not state specifically that there were developments in progress, there could be no doubt, from his remarks, according to *Engineering*, that the *King*

Edward VII. class, of which eight have now been ordered, does not mark finality,—if, indeed, it conforms to present-day conceptions, especially in the matter of gunpower. It is well known that Mr. Philip Watts, the director of naval construction, is now engaged on the completion of a design for ships to be ordered this year; it is premature to indicate the direction in which advance will be made, but there is every reason to anticipate that more guns will be installed. Each of the new fighting ships is likely to cost close upon one and one-half million pounds sterling.

THE chief works of engineering interest in Africa at the present time are the Cape to Cairo and the Uganda railways. Of these *The Engineer*, of London, in its annual engineering review already referred to in an earlier paragraph, says that the Cape to Cairo line is making rapid progress, and has been advanced to the Wankie Coalfields, situated 200 miles north of Bulawayo, and 70 miles south of the Victoria Falls. Wankie coals can now be sent all over the country, which will be a great boon to the northern parts of the Colony, where the supply is very scarce. The railway should reach the Falls next year. The Uganda road is now practically finished, and, as a result, considerable commercial development has taken place among German, Italian, and other foreign firms. By the completion of 300 miles between Bulawayo and Salisbury there is now through communication between Capetown and Beira, a total distance of 2000 miles. The completion of this section will greatly facilitate the progress of the Cape to Cairo undertaking, as railway material can now be supplied to it from both ports. Judging from numerous recent advertisements and from the scheme of construction proposed by the Railway Extension Conference, there ought to be a very fair demand for engineers in the Transvaal and Orange River colonies for some time, and also for large supplies of plant, machinery, bridge material, and other commodities common to constructive engineering. An outlay of £9,000,000 has been apportioned under three heads, —railway extensions, £4,654,000; new railway works, £3,016,635; and general public works, £1,750,000.

AN excellent illustration of the growth of western-world developing influence in the Philippine Islands is afforded by the recent announcement that an order has been closed with the Manila Construction Company, an American corporation conducting operations in the city of Manila, for a complete power equipment for that city's electric traction system, —a turbo-generator installation, in fact, thus representing the most modern idea in electric power generation. There will be three Westinghouse generators, each of 750 KW, and each driven by a Parsons steam turbine. The generators will furnish three-phase, 60-cycle current at 380 volts, part of which will be converted to direct current in the power-house railway substation, while the remainder will go to transformers for supplying the high-tension distributing system. Part of the output will go to the local light and power system.

THE enterprise of the Mysore Government in putting down the large hydro-electric power plant at the Cauvery Falls, in India, of which a comprehensive account was given in this magazine for January, 1903, appears to have been thoroughly successful. The plant was designed for supplying power to the Kolar goldfields, 100 miles away. According to *The Electrical Engineer*, of London, the demand for electric power at the goldfields has greatly increased since the initiation of the scheme, and the generating plant is now to be extended to nearly twice its present capacity. The power house at the base of the hill is to be extended down stream to allow for the installation of five additional generating sets of 720 KW, which will be duplicates of the six now in operation. A new forebay is under construction down stream from the present

forebay, and below the existing step-up transformer station. Five additional pipe lines are to be laid from the new forebay, so that each generating unit will be directly supplied, instead of one pipe line to each pair, as at present. The transformer station also is to be extended, and in order to lessen the line losses consequent on the necessary output, the transmission voltage is to be raised to 35,000 volts. The new electrical machinery is being supplied, as was that originally installed, by the General Electric Company, of Schenectady, New York, U. S. A., and the new turbines, too, come, as before, from the works of Messrs. Escher, Wyss & Co., of Zürich, Switzerland. The cost of the initial installation of about 4500 H. P. is said by *Indian Engineering* to have represented a total capital outlay of £359,817; but deducting the cost of the first year's working and the cost of the compressor houses on the goldfields, which latter is chargeable to the mining companies, the actual capital cost stands at £327,697. The actual power of the initial installation is 500 H. P. greater than was at first contemplated, and the cost per horse-power as originally computed and as now installed works out as £71.84 and £72.82, respectively. The courageous policy of the Mysore Government in entering on this important undertaking receives striking approval from the way the electric power has been taken up by the mining companies, which has necessitated the large expansion of plant indicated above. And it is possible that the city of Bangalore will soon take a supply of energy for lighting purposes, as the transmission line runs within about eighteen miles of the town.

THE most notable engineering event of the year 1903 was the formal opening to traffic, late in December, of the new suspension bridge across the East River, connecting New York and Brooklyn,—the so-called Williamsburg Bridge. The structure is principally remarkable for the fact that it is the largest bridge of its kind in the world. Its total length from street grade to street grade in the two cities is nearly 7300 feet, or about 1300 feet more than the famous old Brooklyn Bridge, and its width is 118 feet. In carrying capacity it exceeds all bridges in existence. It provides for two 18-foot roadways, two footpaths, four street railway tracks, two elevated railway tracks and two bicycle paths. The length of the main span is 1600 feet, or just 5 feet 6 inches more than that of the Brooklyn Bridge. The approach at the Manhattan end is 1562 feet, and at the Brooklyn end, 971 feet. There are four cables, each of thirty-seven strands, each strand made up of 281 wires, so that there are in the four cables 41,588 wires. The steel towers rise 332 feet above high water. They will be increased in height by 20 feet when the ornamental caps to cover the cable saddles are put on. A distinctive feature of the new bridge, leaving aside its great size, is the amount of steel used in its construction. The two towers contain 13,048 tons of steel. The girders in the Brooklyn approach weigh 6085 tons and in the Manhattan approach, 10,550 tons. There are 5000 tons of steel in the cables and other fixtures, and the central span contains 7772 tons more. Taking into consideration steel used in other parts of the structure, the total amount in the bridge is about 40,000 tons. The minimum height of the structure above mean high water at the pierhead is 122 feet. The minimum height above mean high water for 200 feet on each side of the centre of the main span is 135 feet. The height of the masonry in the tower foundations above high water is 23 feet. About 8000 cubic feet of timber, 10,000 cubic yards of concrete and 45,000 cubic yards of stone masonry were used in the construction of the bridge. Taking into consideration the cost of the land and the construction of the bridge, the outlay will be about $20,000,000. The New York tower foundation cost $373,463; Brooklyn tower foundation, $485,082; the anchorages, $1,570,000; steel towers and shore spans, $1,222,726; cables and suspenders, $1,398,000; approaches, $2,411,000; and the main

span's suspended system, $1,123,400. The bridge was designed by Mr. L. L. Buck, M. Am. Soc. C. E.

WITH the recent conversion into an electric slotted conduit railway of one of New York's crosstown lines, hitherto operated by electric storage batteries, it is more than likely that storage battery traction will not soon be revived there; nor is the system likely to receive more favourable consideration elsewhere, if available information of its working abroad may be taken as a guide. Nowhere do storage battery tramcars seem to have given even a reasonable degree of satisfaction, so that the successful battery for that kind of service still remains to be developed.

LEWIS BUCKLEY STILLWELL

Electrical Director of the Interborough Rapid Transit Company, New York

A BIOGRAPHICAL SKETCH

IT is not often that the young engineer, in less than ten years after leaving college, rises to special eminence in his profession. Mr. Stillwell, therefore, ranks conspicuously in engineering circles as a man of unusual achievements, still young and yet most prominently identified since early in the nineties, with the successful working out of some of the world's most important practical engineering problems,—the generation and transmission of Niagara power, for example, the electrification of New York's elevated railway system, and the electric equipment also of New York's rapid transit subway.

Mr. Stillwell was born in Scranton, Pa., March 12, 1963. Although a Pennsylvanian by birth, he is a descendant of an old New York family, prominent in the Colonial history of the province, this name appearing more frequently than any other save one in the lists of members of the Colonial Assembly of New York from 1691 to the time of the Revolution. His father, born in 1824, was a soldier in the Civil War, serving as Captain in the One Hundred and Thirty-second Pennsylvania Vol unteers, and receiving a severe wound at the assault on Marye's Heights at the battle of Fredericksburg. Subsequent to the war he acted for many years as general superintendent of anthracite coal breakers of the Pennsylvania Coal Company.

On his mother's side, he is of German stock, his mother being a granddaughter of General Peter Kichlein (1722-1789), member of the Committee of Safety of the Colonies (1774-1776), and greatly distinguished at the battle of Long Island, where he commanded a regiment of Pennsylvania riflemen, which, at the cost of nearly half its numbers, held its position until the American line being broken elsewhere, practically the entire remnant of the regiment, including its Colonel, was captured.

He was graduated at the Scranton High School, matriculated at Wesleyan University, and after two years' work there took up the study of electrical engineering at Lehigh University, where he completed the electrical course in 1885, taking post-graduate work at Lehigh in mechanical engineering, 1885-86. In October, 1886, he accepted the position of assistant electrician of the Westinghouse Electric & Manufacturing Company, of Pittsburgh, Pa., where he was associated with O. B. Shallenberger, William Stanley and Nikola Tesla, particularly in the commercial development of the alternating-

current systems of lighting and power distribution.

In April, 1890, he was promoted to chief electrical engineer, and in April, 1895, to chief electrical engineer and assistant manager. In March, 1897, he resigned and became electrical director of the Cataract Construction Company and Niagara Falls Power Company, at Niagara Falls, N. Y., having while with the Westinghouse Company directed the preparation of the plans for the electrical utilisation of Niagara which were finally adopted by the Cataract Construction Company.

At Niagara he became responsible not only for the work of electrical construction in connection with the extensions of the installation, but also of the operation of the plant as completed. During his residence at Niagara many of the problems met with in electrically transmitting and distributing power at high potential and in great amount for industrial purposes, as well as for lighting and for the operation of street railways, were encountered for the first time in commercial service, and to their solution and to the organisation of the operating force and methods of the company he devoted the greater part of his time for the ensuing three years. While thus engaged, he made an exhaustive study of the subject of charges for power, as fixed by cost of production and by cost of power developed by competing steam plants, and prepared a schedule of charges which was adopted by the Niagara Falls Power Company and has since served as the basis for its contracts throughout the territory supplied from its plants. He also prepared a system of classification of accounts for the operating department which has since been used by the company.

While at Niagara, he acted as consulting engineer for various enterprises other than the Niagara development, and in March, 1899, accepted the position of consulting electrical engineer to the Manhattan Railway Company, of New York City, taking charge of the design and installation of the complete electrical equipment of the elevated lines. In September, 1900, the first power plant at Niagara being completed and in successful operation, he resigned his position with the Niagara companies to give his entire time to the Manhattan Railway Company and to practice as consulting engineer in the city of New York. He subsequently received from the president of the Cataract Construction Company the Niagara medal, designed by MacMonnies and engraved by Paulin Tasset.

In November, 1900, he became electrical director of the Rapid Transit Subway Construction Company, now the Interborough Rapid Transit Company of New York, in addition to his other official and professional duties.

Mr. Stillwell has patented a number of important inventions having to do with the practical application and use of electricity in power transmission and railway practice. He is a member of the American Philosophical Society; the American Society of Civil Engineers; the American Institute of Electrical Engineers; the British Institution of Electrical Engineers, and of many other scientific and engineering societies. His scientific papers, presented before technical societies and in some of the leading technical periodicals, include the following:—"The Electrical Transmission of Power from Niagara Falls"; "Frequency in Alternating Current Plants for Lighting and Power"; "The Relation of Size and Efficiency in Transformers"; "Possibilities of Electrical Transmission and Distribution of Power in Pittsburgh"; "Electrical Equipment of the Manhattan Railway Company"; and "Electric Power Generation at Niagara," this last having been prepared specially for the Niagara Power Number of CASSIER'S MAGAZINE, published in 1895.

PAUL M. LINCOLN

ELECTRICAL ENGINEER OF THE WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

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CASSIER'S MAGAZINE

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GAS POWER FOR HIGH-PRESSURE CITY FIRE SERVICE

THE PHILADELPHIA HIGH-PRESSURE PUMPING STATION

By J. R. Bibbins

THE establishment of a central pumping station operated by gas power for serving high-pressure fire mains in congested city districts is a decided step in advance in municipal enterprises. Recent successful tests upon the completed system of the city of Philadelphia furnish the best evidence of the soundness of engineering judgment in selecting gas engines as the prime movers for this important service. The equipment of the Philadelphia system is without precedent in the history of large fire protection systems, and likewise marks a new era in the introduction of the internal combustion motor.

The problem of furnishing adequate fire protection to business districts in large cities is of the greatest importance, both from the standpoint of finance as well as of public safety. It is an engineering problem that is forcing itself into public consideration by virtue of the enormous losses incurred by insurance companies in these districts, which ultimately react upon the public in the form of increased insurance rates. On the one hand the establishment of the modern skyscraper in business centres, and on the other the increased risk from heavily depreciated structures in contiguous districts have necessitated the provision of special means for overcoming difficulties not formerly encountered in fire-fighting. In the one case effective heads of 500 to 1000 feet at the pumps are required, and in the other enormous volumes of water, available at many points.

In New York, Chicago and other American cities many office buildings approach or exceed 300 feet in height, which altitude imposes at the start a head of approximately 150 pounds per square inch in addition to that necessary to overcome friction. The limit of bulk and capacity has nearly been reached in portable fire-fighting apparatus, particularly in metropolitan business districts. Some streets, laid out many years ago, have become deficient in width for the accommodation of normal pedestrian and vehicular traffic. With the added congestion due to public excitement, the efficient manipulation of the large fire engines necessary to cope with high alti-

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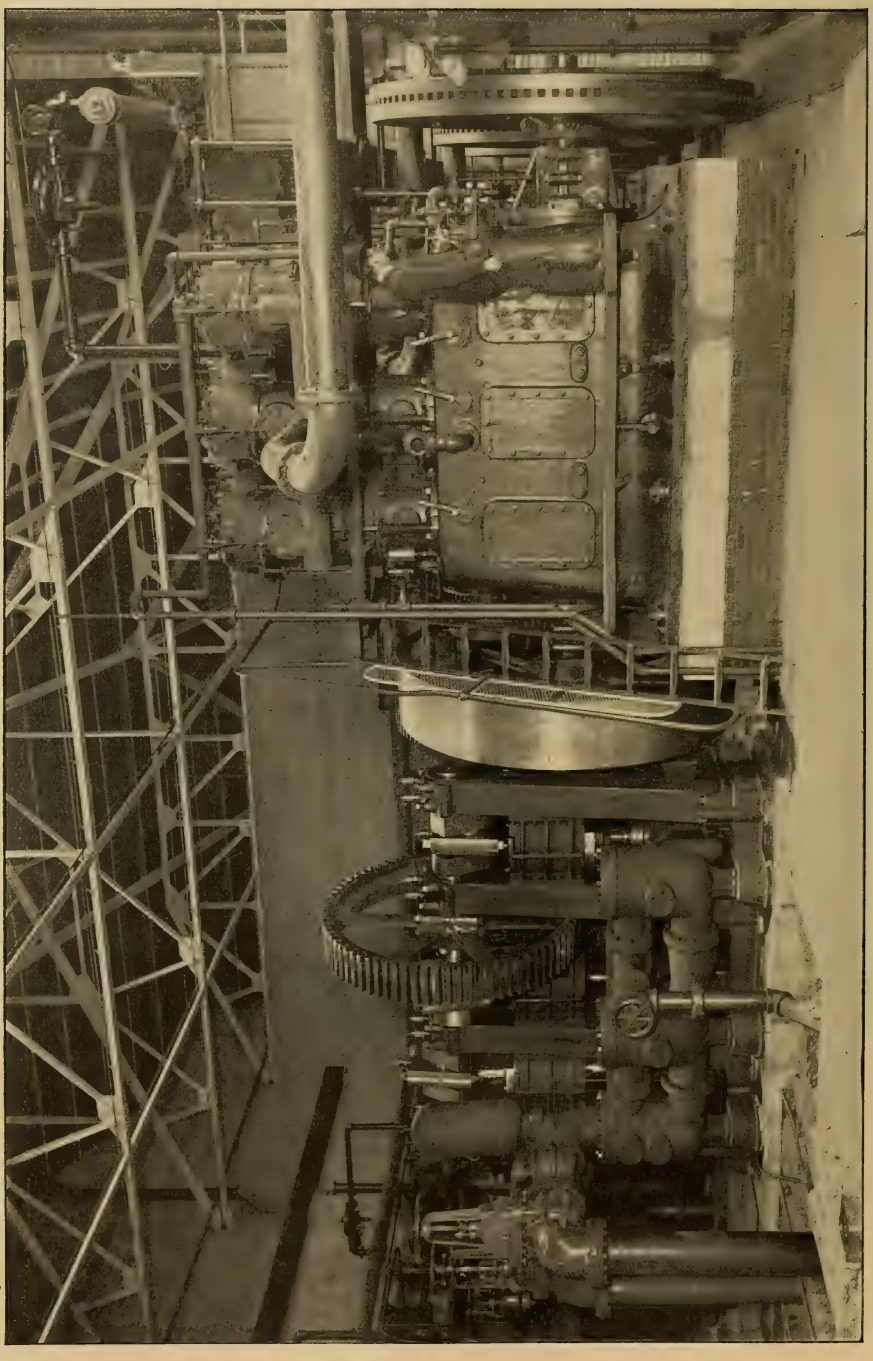


FIG. 1.—SIDE VIEW OF A COMPLETE 300 B. H. P. 2,000,000-GALLON GAS ENGINE PUMP UNIT, SHOWING METHOD OF STARTING

FIG. 2.—THE PUMPING STATION. NOTE THE ABSENCE OF THE USUAL CHIMNEY, DUE TO THE USE OF GAS ENGINES

tudes becomes almost an impossibility. Under such conditions, the obvious remedy is an independent high-pressure pipe system, receiving its water supply from a conveniently located central pumping plant, and provided with numerous hydrants suitable for the direct attachment of the heaviest hose lines without the intermediary fire engine. With such a system individual buildings equipped with standpipes may be constantly connected to the fire system and kept under pressure. The loss of time in approaching the fire and arranging hose and street apparatus may then be avoided.

Most large cities of historical importance contain districts, formerly flourishing business centres, but now in such a state of decadence as to constitute a growing menace to the safety of the present business districts, usually contiguous thereto. Such is the case in Philadelphia, and so important have been the losses from fire in the lower sections of the city, due to the above mentioned causes, that insurance companies in self-defence have been obliged to increase rates to cover the increased risk.

The high-service system at present draws its water supply entirely from the Delaware River, the pumping station being located on the river front. After having its pressure raised to the required amount, the water passes into a 20-inch distributing main along the river front, which supplies 12 and 16-inch mains extending into the business district. These are tied together into a network at five points by cross mains. The pipe network consists throughout of cast iron pipe laid in 12-foot lengths, suitable for a working pressure of 300 pounds per square inch. It is provided with special expansion joints at intervals of 200 to 500 feet, and long-radius sweep bands at all turns. Stop valves at every corner, or at intermediate points, provide means for localising damage due to a ruptured section of piping, thus avoiding the crippling of more than one hydrant. Each hydrant has two 4-inch nozzles, to each of which manifold connections may be attached, supplying in all six hose lines.

Telephone boxes are provided at each street intersection, communicating with the central office at fire headquarters, from which operating orders may be transmitted to all points of the system.

As originally laid out, the pipe system was arranged for connection to fire boats plying along the river front. Three "Siamese" or manifold connectors were provided at the bulkhead to which the boats might be connected, according to the location of the fire. With the establishment of the present pumping station, the fire boats will be held as a reserve, to be operated as before.

A supplementary source of water supply is provided at the extreme end of

FIG. 3.—THE UNDERWRITERS' TEST

the line, where permanent connection has been made with a 12-inch main leading directly from a reservoir supplied from the Schuylkill River. The elevation of this reservoir imposes a constant gravity head of 70 to 80 pounds pressure upon the high service system, which is sufficient for flushing and for locating faults in the piping. A check valve at the point of connection closes when the station pumps are started, thus automatically maintaining a moderate pressure at all times upon the system.

The utilisation of fire boats for serving the high-pressure system was adopted as a temporary expedient pending the completion of the central pumping station. These boats, however, are now held as a reserve and for use along the water front. They have an aggregate capacity of 9000 gallons per minute, and have maintained twelve 1¼-inch

FIG. 4.—ANOTHER VIEW SHOWING A VERTICAL STREAM

streams, connected to the system a mile and a half distant, with an average pressure of 180 pounds at the pump. Four 2-inch streams were similarly maintained with a pressure of 237 pounds at the pump. Under these conditions a loss in pressure of 47 per cent. in the first case and 34 per cent. in the second was observed from pump to hydrant in use. The average horizontal distances covered by the streams were 150 feet and 190 feet, respectively; while a single 2-inch stream covered 315 feet horizontal and 230 feet vertical distance with a pressure of 230 pounds at the pumps.

In the face of these excellent results it became apparent that for effective service at distant points even greater power is required than that available with fire boats, by reason of the unavoidable losses occurring in the pipe

FIG. 5.—A NEAR VIEW OF THE FIRE STREAMS UNDER TEST

line. The central high-pressure pumping station was thus evolved from the experience gained in the use of fire boats. By its use unlimited pumping capacity may be concentrated in a minimum area, and the effectiveness of the apparatus may be made quite independent of climatic conditions. Furthermore, this apparatus, being brought under the direct supervision of a single departmental chief, may be handled in a more intelligent and efficient manner, and the delays incident to the connecting-up of a movable source of power may be entirely avoided.

The possibility of subdivision of power units to any desired degree forms one of the most desirable features of the central station arrangement. It is evident that the risk from disablement of power machinery varies inversely with the number of units installed; and the provision of an extra unit for substitution service provides means for conducting, in rotation, inspection of the equipment without the danger of crippling the service by the loss of the machine under inspection. With small units, therefore, relay capacity can be provided at minimum cost. Although high

economy of fuel is not a vitally important qualification, such is desirable, as a considerable amount of fuel is consumed in periodical testing of equipment. It is, therefore, necessary to employ a source of power reasonably efficient in small sizes.

The gas engine as a prime mover for this important service has two close competitors, the steam-driven pump and the electric motor-driven pump. The former has in its favour extensive development and wide usage; the latter, the ease and convenience with which power may be applied to the pump. In the present instance electric power was first considered, but soon abandoned, for the following reasons:—Liability of accident to power house and supply line, due to short circuits and other causes; control of entire fire situation in the hands of independent corporations; obvious futility of constructing a special electric generating station.

The use of steam power likewise presents important difficulties. According to a recent authoritative utterance, "it must be confessed that the cost of maintaining a steam plant ready for instant operation throughout the year is rather staggering to the municipal mind in a department where all is outgo and there is no income." This cost arises from the necessity of constantly maintaining full head of steam and banked fires, with attendant losses in many directions. The entire boiler equipment must, furthermore, be under steam, as any demand up to full capacity of the pumps is liable to occur at any moment.

The selection of the gas engine as a motive power brings into prominence its unique characteristics for this intermittent service. Although extreme conservatism in the matter of fire risks is highly preferable to the reverse, considerable adverse criticism attended the substitution of gas for steam power. This criticism, however, finally culminated in the tacit admission that "there is no mechanical objection (to gas engines) if pumps and engines can be made reliable for such a serious purpose."

Familiarity with the late phenomenal development of American and European gas-power machinery can scarcely have inspired this objection. There are few forms of motors that can exhibit a service record equal to the following obtained from a gas engine of the same construction as those of the Philadelphia plant—

Total elapsed time	8,472 hours.
Hours run	8,230 "
" "	97 per cent.
Hours shut down (chargeable to engine)	51 hours.
" " "	0.6 per cent.
Run without stopping	1,157 hours.
" " " (24 hour days).	48 ds., 5 hrs.

Shutdown to repair a broken belt.

In a 500 H. P. gas-power pumping station a short distance from Pittsburgh each engine unit operates from 96 to 98 per cent. of the elapsed time, being shut down only for a few hours on Sundays for inspection.

Returning to the subject of steam *vs.* gas power, a report of F. L. Hand, chief of the Water Bureau of Philadelphia, shows clearly the facts in the case. The figures cover estimated operating cost per month exclusive of fixed charges and upon the basis of one fire per month of ten hours' duration.

Items	Steam Plant	Gas Plant
Number of engines	3	8
Capacity million gallons per 24 hours	15	16
Number boilers	8	none
Cost—engines, boilers and stack	$140,000.00	--------
Cost, engine	--------	$150,000.00
Wages per month	650.00	450.00
Cost coal at $2.00 per ton	500.00	--------
Cost gas at $1.00 per M	--------	392.00
Cost fuel per hour	50.00	39.20
Oil, waste	48 00	48.00
Repairs	85.00	85.00
Total cost per month	$1,283 00	$975.00
Cost per year	15,396.00	11,700.00

Saving in per cent. of steam plant.. 24 per cent
Saving basis equal capacity..... 23 "

Commenting upon these figures, Chief Hand says:—"The cost of running per year will show a much greater difference in favour of the gas engine than is shown in the table, from the fact that gas is used only when required, which might be considerably less than ten hours per month. * * * The first cost of a gas engine and pump is greater than that of a steam engine and pump; but the additional cost of boilers and stack for the latter, neither of which is required for

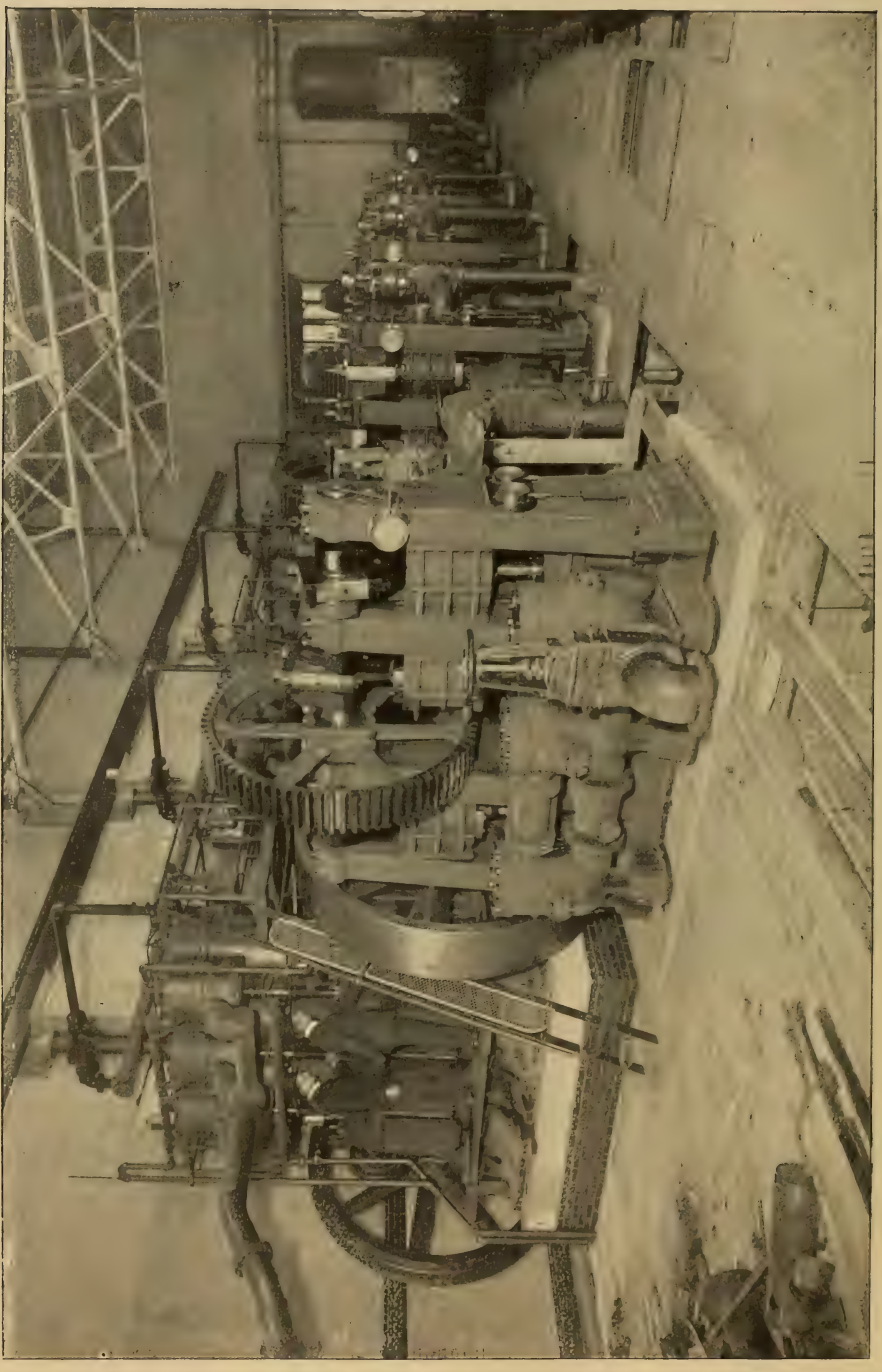


FIG. 6.—AN INTERIOR VIEW OF THE PUMPING STATION, SHOWING ONE ROW OF PUMPING UNITS

a gas engine, makes the total cost of the two plants nearly equal."

The figures in the table do not, however, tell the whole story. Including fixed charges in the total operating expense, the saving becomes still greater. Upon the basis of the above figures the fixed costs are as follows:—

	Steam	Gas
Capacity—gallons per 24 hours	15,000,000	21,000,000
Building	$50,000	$50,000
Sub-foundations	7,500	7,500
Machinery and foundations	175,000	200,000
Total	$232,500	$257,500
Cost steam plant on pro rata basis, equal capacity	$326,000	
Cost equipment per million gallons capacity	15,500	$12,250
Interest on investment, 5 per ct.	16,300	12,875
Depreciation, average 7.5 per ct.	24,450	19,300
Insurance and taxes	none	none
Total	$40,750	$32,175
Saving	$8,575 = 21 per cent.	

Summary of Saving—Gas over Steam.

Initial total cost of equipment	21 per cent.
Estimated operating cost	29 "
Estimated fixed charges	21 "
Total operating cost	50 "

Although estimated percentages are subject to much modification by variable local conditions, these figures given are directly applicable to the Philadelphia plant under the assumptions named. As an example, treacherous subsoil was encountered which added 15 per cent. to the cost of building construction. The general saving due to the use of gas-power shows, then, not only in net operating cost comprising fuel, labour, and repairs, but also in cost of equipment and fixed charges, which form as legitimate a factor in total operating expense as the cost of fuel itself.

In building cost alone 35 per cent. are saved by the general compactness of the machinery and the dispensing with a boiler house. Considering, in addition, the immense improvement in simplicity of operation by doing away with boilers, heaters, pumps, condensers and piping under pressure, as well as absence of standing losses, the gas engine would seem to be ideally fitted for this pumping station service.

Recent trials of the Philadelphia equipment certainly point to entire fulfilment of prophesies. One object has at least been attained,—the removal of an advance in insurance rates in the district served.

THE PUMPING STATION

In preparing the site for the pumping station on the Delaware River, an unexpected difficulty was encountered in the unsubstantial character of the subsoil, which proved to be little better than river-bed muck. About 9 feet below the surface the well-preserved planks of an old plank road were unearthed, presumably antedating by many decades the building razed.

The sub-foundation of the building consists of a solid concrete bed 5 feet in thickness, this bed being reinforced by a steel construction of 1-inch round rods imbedded near the upper and lower surfaces of the concrete. The building foundations and engine piers rest directly upon this sub-foundation, which added over 12 per cent. to the expense of the structure. The maximum concentrated load upon the concrete bed is

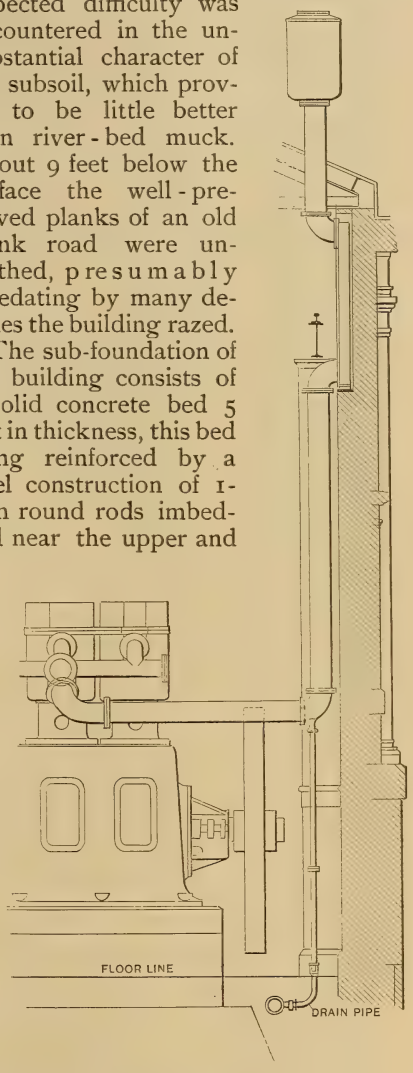


FIG. 7.—THE LAY-OUT OF THE EXHAUST PIPES

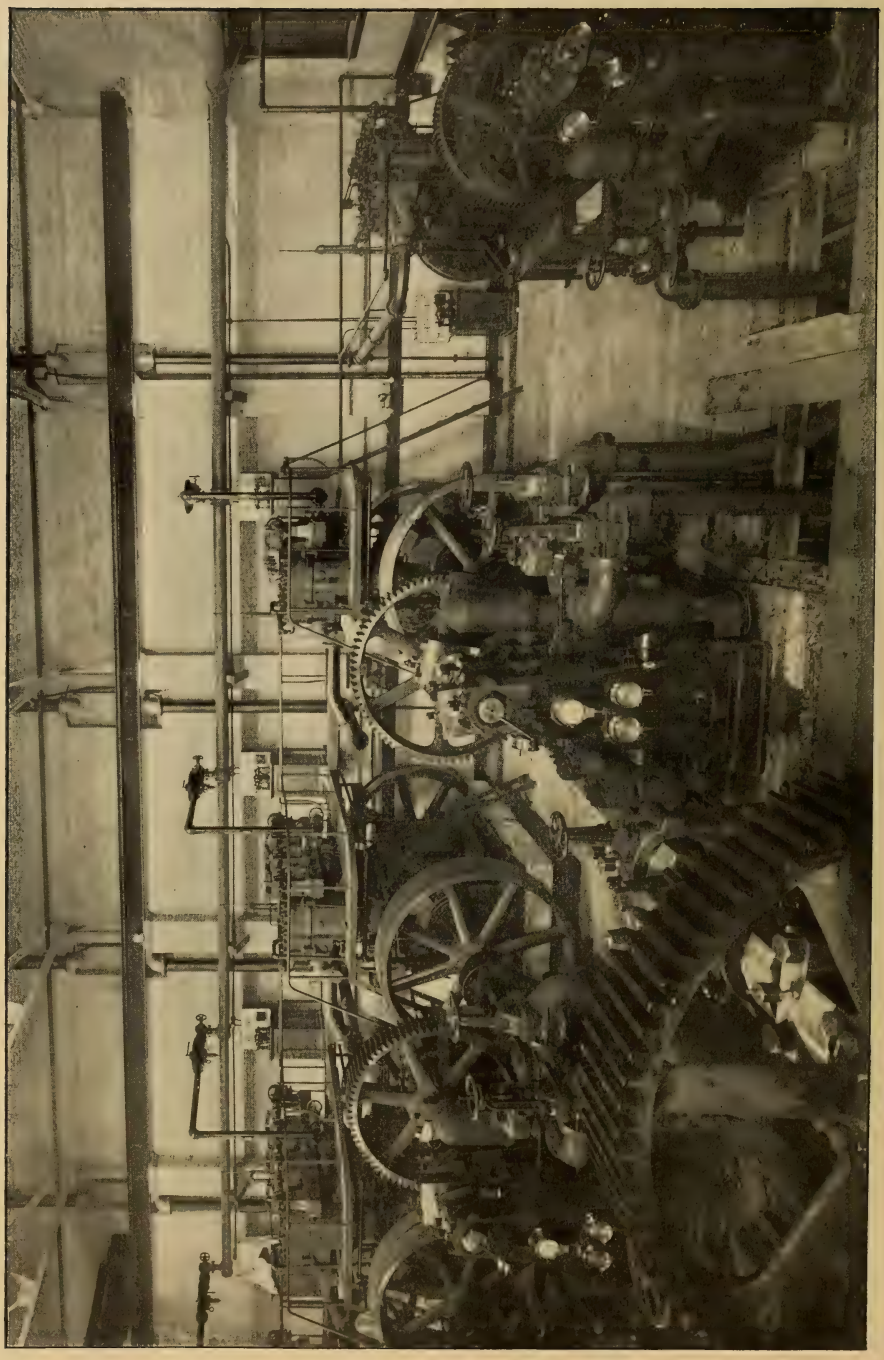


FIG. 8.—THE PUMPING STATION INTERIOR SEEN FROM THE ENGINE GALLERY

about 4000 pounds per square foot. The general character of the building is worthy of the enterprise. Dark-red, smooth-finished brick, terra cotta trimmings and window arches, slate roof and copper monitor secure an exceedingly handsome exterior In the interior, brick of light reddish tint is employed with a wainscot of cream glazed brick, trimmed by a dark belt course of similar material. The floors are of concrete, and the engine piers, extending above the floor level, are finished with glazed brick in harmony with the wainscot. In the western and upper end of the building are capacious offices and a lavatory for the operating force. An 8-foot basement accommodates plant auxiliaries,—air compressors, storage tanks, igniters, generators and building heating apparatus, as shown in Fig. 11. The engine room is approximately 130 × 68 feet, including the basement. It is spanned by a 6-ton travelling crane.

The engine room at present contains nine pumping units. Seven of these are 300 B. H. P., 2-million-gallon units, and the other two are 125 H. P., 1¾-million-gallon units. Space exists for three additional of the larger units, which will be installed when the service demands greater capacity. In addition to the pumps, each of the smaller engines drives an igniter-generator and compressor.

The gas supply of the plant is drawn from a 24-inch trunk main connecting two large gas holders of the local illuminating gas supply system. A 16-inch branch, controlled by a street valve, divides inside the station into the 12-inch main supplying the two lines of engines. The average analysis of the gas is as follows:—

Carbon dioxide	2.89 per cent.
Oxygen	0.60 "
Hydrogen	32.70 "
Carbon monoxide	21.20 "
Methane	26.30 "
Nitrogen	4.70 "
Illuminants	11.61 "

This gas averages about 23 candle-power, and is quite uniform in quality, the maximum variation from the average during 1902 being about one per cent. Tests have shown the average calorific value of the gas to be about 675 B. T. U. per cubic foot. This gas, therefore, furnishes an excellent source of power to the pumping station.

The percentage of hydrogen is not sufficiently high to cause backfiring, and no trouble has been anticipated or experienced from this source. As the plant draws its supply from two of the largest holders in the city, each independent of the other, the possibilities of an interruption of service are evidently remote. Should an accident occur to one of the units within the station, the supply valve may be closed at the station main, thus completely isolating the disabled unit and avoiding the crippling of one half of the station. The normal capacity of the plant would be reduced but 13 per cent. with one unit out of service.

THE ENGINES

As the use of gas engines constitutes the principal feature of interest in the plant, a brief description of the equipment is here given. The engines are all of the vertical, three-cylinder, single-acting type, operating upon the four-stroke cycle, thus giving a power stroke at each two-thirds of a revolution. The construction employed is that of the standard Westinghouse gas engine, and the engine is, therefore, not a motor designed particularly for this service, but one that has been developed as a result of a number of years' trial in many other forms of power service.

The most striking feature of the engine is its enclosed or self-contained construction, the shaft, cranks, and connecting-rods being enclosed in a housing provided with suitable manholes for ready access to the working parts. This housing is filled with oil to such a height that the cranks during their revolutions dip into this oil and furnish "splash" lubrication to all interior working parts. The most important duties of the oiler are thus eliminated. Upon the two ends of the housing are mounted the bearings, which are adjustable, to compensate for wear, and are each removable in one piece. The cylinders, which are provided with jackets for water cooling, are mounted directly

upon the housing, and contain long trunk pistons, thus dispensing with the usual engine cross-head, and affording great structural strength and considerable saving of space.

A platform extends around the engines at about 10 feet from the engine room floor, serving as a working platform for operating the engine throttles and inspecting the valve gear. These platforms are interconnected between engines, so that a continuous runway is formed, extending from one end of the power station to the other. Upon this gallery are mounted the igniter cabinets referred to further on. A sub-platform is also bolted to the engine casing for convenience in operating the air-starting mechanism. This is shown in Fig. 1.

In the principle of regulation employed no idle strokes are admissible, as in the case of so-called "hit-and-miss" governing. The arrangement of the valve mechanism is such that a charge of explosive mixture of constant and uniform quality is admitted to the cylinder at every other stroke, and is, in turn, ignited at the succeeding stroke. This secures a uniformity of effort upon the crankshaft superior to that obtained by the other method. The proportioning of the power generated to the load upon the engine is performed by a centrifugal governor positively operated through gearing from the crankshaft. The governor controls the admission of a variable quantity of mixture to the cylinders, according to the load.

For purposes of pump driving this method of governing is particularly desirable, as through the uniformity of rotation heavy wear on the gears and sudden thrusts upon the incompressible water in pump cylinders is avoided.

Power gas is supplied to the units at approximately atmospheric pressure, the reduction in pressure from that of the street main being accomplished by automatic regulators inserted in each supply pipe. These are easily within reach from the gallery, and may be adjusted at any time so as to maintain zero pressure upon the engines, as indicated by a manometer gauge. This gauge is in constant view of the attendant, so that the slightest irregular working of the regulator may at once be detected. A valve back of each regulator and the main throttle valve at the engine provides means for controlling the engines and removing the regulators for inspection if necessary. Ordinarily the former is left open in order to reduce the duties of the attendant in starting. From the throttle gas enters a combined mixing and governor valve, which may be adjusted by means of graduated levers for the most efficient mixture of gas and air. This adjustment, once made, need not be changed for a gas of constant quality. The valve is directly controlled by the governor and supplies mixture to the three main admission valves on the cylinder.

Both admission and exhaust valves are plain discs, seating vertically in the direction of the internal pressure, so that comparatively light mechanism is required to operate them. Cams are used for this purpose, arranged on lay shafts geared to the main shaft. The upper lay shaft likewise operates the igniters. Both sets of valves may be removed, for inspection, through the cylinder head. Those of the exhaust are water-cooled to insure longer life.

Ignition of the mixture under compression is accomplished by an electric igniter of the "make and break" type, removable for cleaning in the form of a single plug. Two igniters are supplied in all engines for increased surety of operation. By means of a throw-over switch the ignition current may be transferred to the reserve igniter on any cylinder.

Cooling water for cylinders, heads, valves, and exhaust mains is controlled by a single valve. The relative amounts supplied to the several parts are, however, permanently adjusted by individual valves. To prevent the jackets being drained when the plant is idle, a water-seal is fitted to each engine with a short stand-pipe clearly shown in Fig. 1 at the upper left hand corner of the engine. This is open to the atmosphere and serves as a "tell-tale." If the overflow pipe becomes stopped, water will be poured out of the pipe, or

if the engines after starting are allowed to run too long without sufficient cooling water, steam will issue from the vent. No harm would ordinarily ensue from these causes unless the warnings are entirely disregarded.

Flooding of the cylinders from cooling water turned into the exhaust main is prevented by the drain pipe shown in Fig. 7. This pipe connects directly with the sewer without an intermediate valve, and the general slope of the piping forms a water pocket at its junction with the exhaust main. Cast iron piping conveys the exhaust gases to the roof, and terminates in a cast iron exhaust-head, which serves as a muffle and trap. In passing the crane track a special cast iron box is used to obtain the desired effect, as shown in both Figs. 7 and 8.

Starting of the engines is accomplished through the agency of compressed air at 150 to 200 pounds pressure. As the pumps are arranged for starting without load, the work done by the engine is that of friction alone. As this is largely a matter of adjustment of parts, particularly plunger packings, 200 pounds air pressure has been provided in case a lower pressure should be inadequate. A pressure of 100 pounds has, however, been found quite sufficient under any conditions.

In starting, the valve mechanism of the end cylinder is temporarily isolated by means of the lever which the operator is shown handling in Fig. 1, while by operating another one close at hand compressed air is admitted to the cylinder which acts as an air motor. In two or three revolutions the normal explosion cycle is started in the remaining cylinders, the compressed air is shut off, and the exhaust valves are thrown into action in quick succession by the levers shown at the back of the operator. (Fig 1). The stopping of the engine at the proper point for starting is accomplished with ordinary care or by manipulation of the compressed air valve if necessary. If the point be passed, the engine can be readily notched around by a lever engaging notches in the flywheel.

IGNITION CURRENT SUPPLY

Constituting, as it does, one of the most vital points in the operation of the engines, special precautions were observed by the engineers in providing reserve sources of supply. Each engine is furnished with an igniter cabinet, shown in Fig. 14. These are located near the engine throttle upon the upper galleries. One row of these appears in Fig. 8.

Three sources of current are available at each cabinet and are there controlled by switches. Current is regularly supplied from a duplicate set of 7½ KW, 220-volt, direct-current generators, belted to the smaller engines. This voltage is reduced to 110 volts by individual motor-generators. The igniter current may, however, be drawn directly from the 220-volt main in case of emergency. If the station generators fail, 220-volt Edison current is available for the motor generators, and finally current at 8 volts from primary cells in the cabinet.

No arrangement of switches will result in interference with other sources of supply, and the hasty closing of one switch will always result in current at the igniters.

In starting the station one of the emergency sources may at first be used and the motor-generators afterward started at leisure. All igniter as well as station wiring is run in insulated iron pipe duct with cast iron junction and outlet boxes, thus insuring the greatest safety against interruption.

COMPRESSED AIR SYSTEM

Sufficient compressed air is kept continually stored in tanks to start the entire station without aid from the air compressor. The total capacity would, however, seldom be required, and in that event the compressors would be in action to replenish the supply. The air is furnished by a duplicate set of two-stage compressors, shown in Fig. 11, each provided with an automatic unloader valve which opens above 200 pounds pressure and relieves the pump from duty, although it may still be in operation. If the pressure falls below

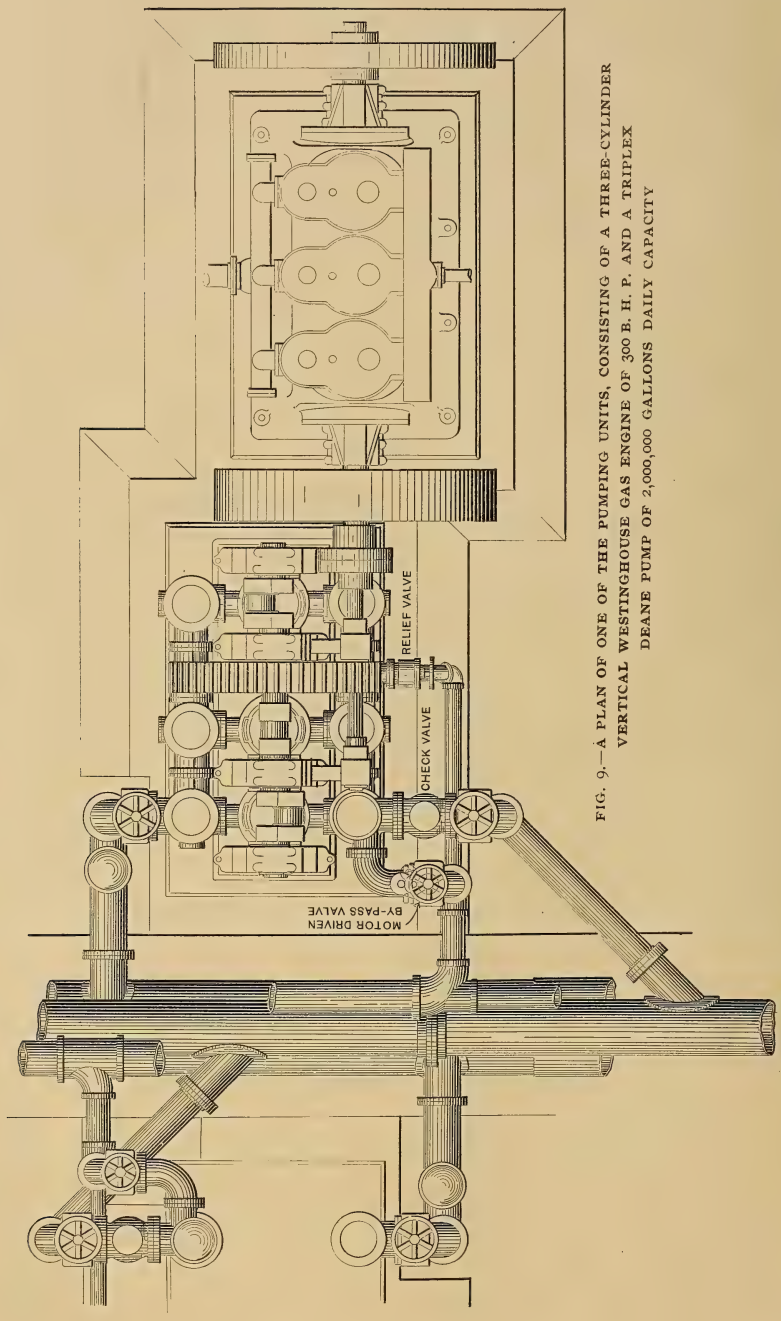


FIG. 9.—A PLAN OF ONE OF THE PUMPING UNITS, CONSISTING OF A THREE-CYLINDER VERTICAL WESTINGHOUSE GAS ENGINE OF 300 B. H. P. AND A TRIPLEX DEANE PUMP OF 2,000,000 GALLONS DAILY CAPACITY

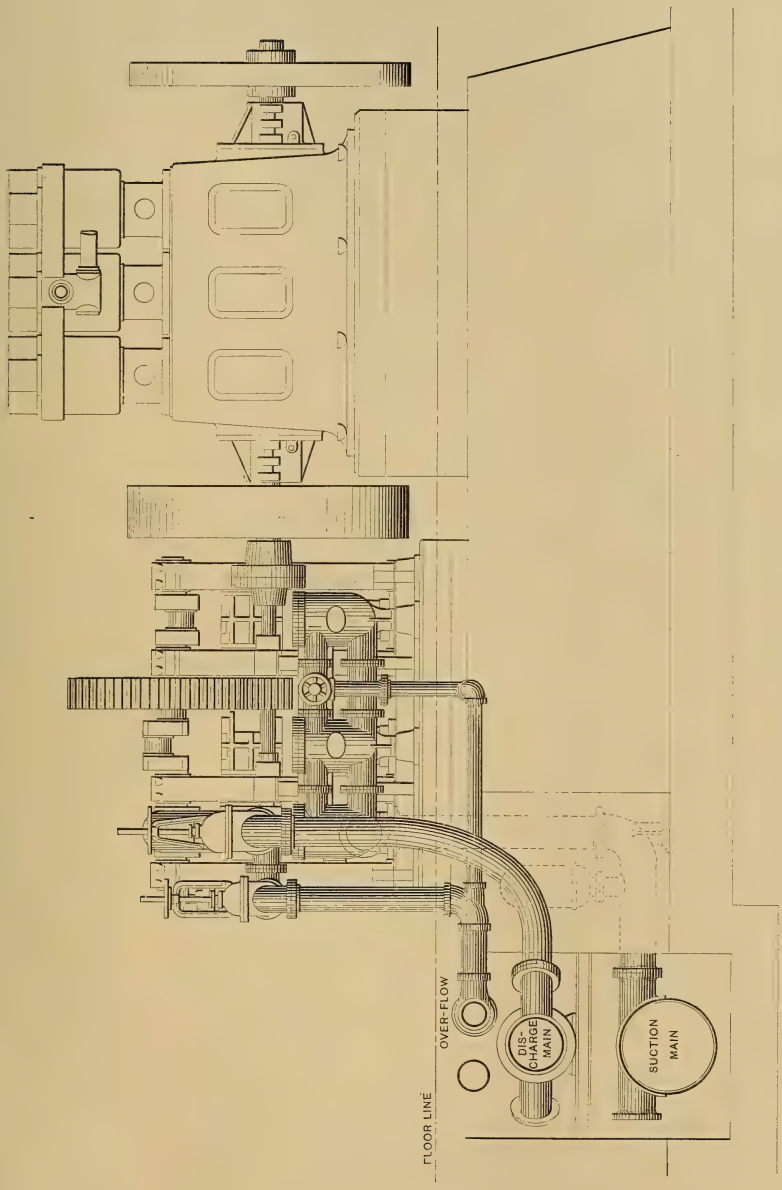


FIG. 10.—AN ELEVATION OF ONE OF THE PUMPING UNITS

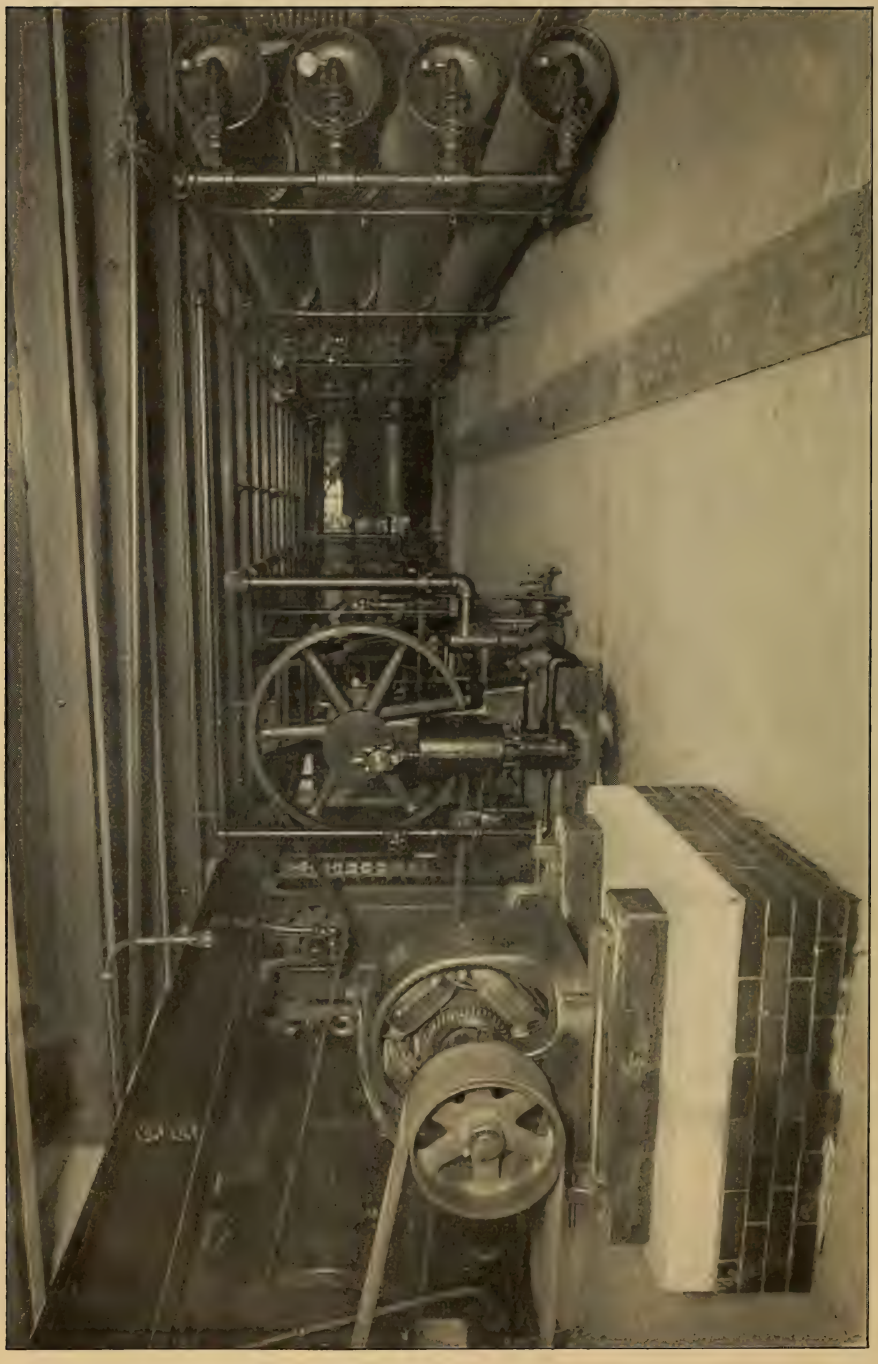


FIG. 11.—A VIEW IN THE BASEMENT, SHOWING GENERATORS, AIR COMPRESSORS, AND AIR STORAGE TANKS

200 pounds, the valve again places the pump in action. The air is stored in eight seamless steel tanks 16 inches in diameter and 15 feet long. These are shown in Fig. 11, with the method of support and the controlling valves. Each tank may be isolated at will, to be held, for instance, as a reserve. The two banks are also connected in duplicate for this purpose.

THE PUMPING MACHINERY

The pumping machinery was constructed to meet special specifications in which a considerable improvement over standard practice was contemplated.

The general design is that of the standard triplex, double-acting, inside packed type of single-geared plunger pump of the Deane Steam Pump Company, of Holyoke, Mass., but several new features have been incorporated. The triplex design was selected because of the uniform discharge to be secured, which, at the high pressure employed on the mains, becomes imperative. Specially massive construction has been employed, together with composition bronze in all internal fittings, to secure easy starting after periods of idleness. One of the large pumps is shown in Fig. 13.

The water ends are constructed in sections with unusually large valve areas. Suction and discharge boxes are cast separate from the pump barrels, which, in turn, are separate from the base. The three resulting sections of the pump are united by bolted flanges, and the replacement of any part may thus be accomplished without disturbing the adjustment of the remaining parts. All moving parts are adjustable to compensate for wear.

A striking feature is the provision of a motor-driven by-pass valve, controlled from a position in the centre aisle in front of the gauge board. This valve is left open during the starting of the unit, and when full speed has been reached, it is closed by the motor and diverts the pump discharge from the overflow to the station discharge main leading to the high-pressure system. This operation allows the pump to start up under friction load, and the discharge pressure is gradually increased to full working pressure during the closing of the valve, thus avoiding all shock to the machinery or system. It also does away with the clutch coupling, which would otherwise be necessary.

The valve and motor are illustrated in outline in Fig. 12; its position is shown in Fig. 9. The motor is controlled by a double-throw switch. A simple series motor is used, and a reversal of the switch opens or closes the valve at any desired speed. Usually the unit may be started within the time required for the valve to seat, so that the switch may

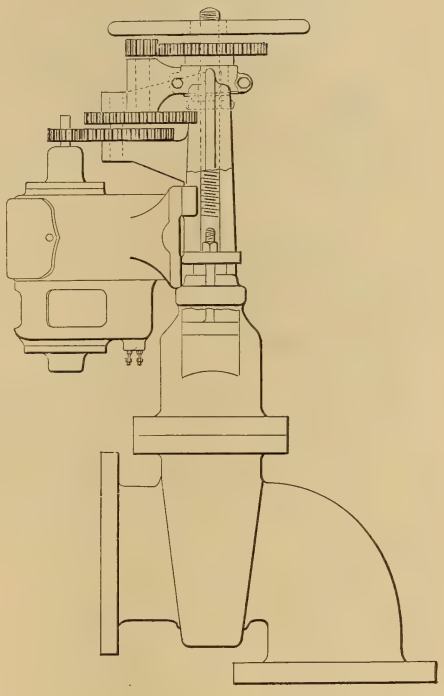


FIG. 12.—ONE OF THE ELECTRICALLY OPERATED VALVES, SEE FIG. 9. MADE BY THE CHAPMAN VALVE MFG. CO., INDIAN ORCHARD, MASS.

be closed shortly after the signal, and about fifteen seconds may be saved thereby. An automatic relief valve upon the discharge chamber of the pump serves to protect the latter against excessive pressure. This valve is used also during the daily tests of the equip-

ment, to obtain the normal working pressure when the pump discharge is throttled by the by-pass valve. A check valve in each discharge protects

of daily tests, and, in case of fires, the duration of high-pressure service. These records, kept on file, evidently furnish absolute evidence in the event of criti-

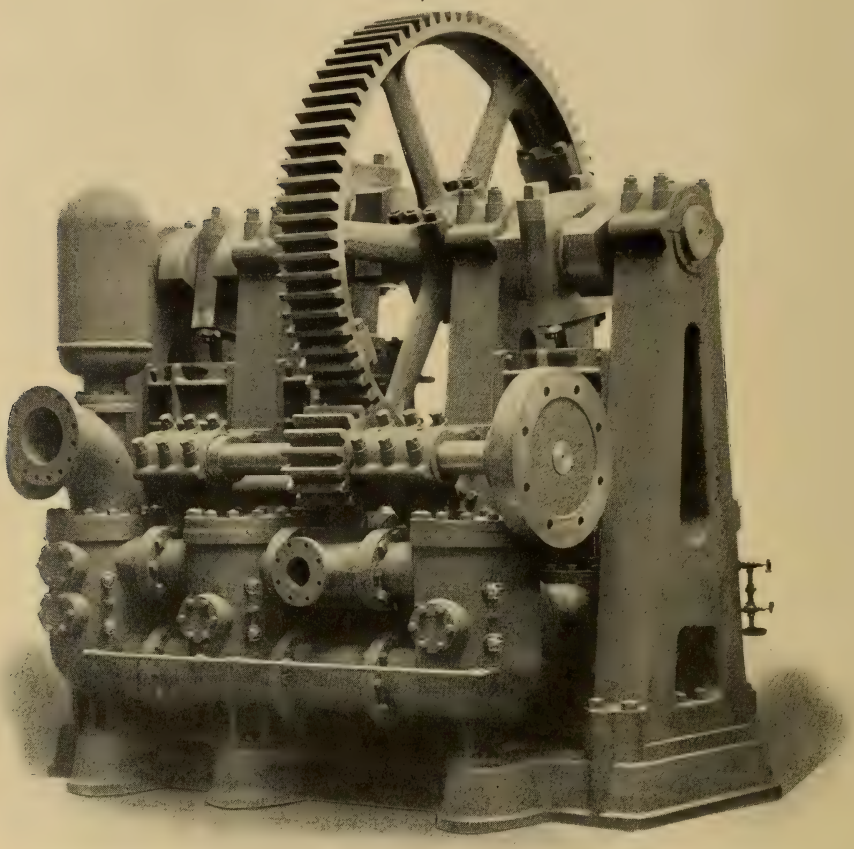


FIG. 13.—ONE OF THE 2,000,000-GALLON PUMPS. MADE BY THE DEANE STEAM PUMP CO., HOLYOKE, MASS.

an idle pump against back pressure from other units in operation.

The smaller units are similar in equipment to the larger ones, with the exception that a friction clutch is used in place of the by-pass. This is necessary, as the engines are used also for driving auxiliaries.

Each pumping unit is supplied with a gauge board, as shown in Figs. 6 and 8. A twenty-four-hour recording pressure gauge furnishes a daily record of the operation of the station and the time

cism of the service subsequently arising. Two ordinary gauges indicate the suction lift and the discharge pressure, the former readily detecting a stoppage of the intake or unseating of the pump valves by foreign matter. The output of the unit is determined by a speed counter mounted upon the pump frame. With the plunger displacement and the discharge pressure available, the output of the engines may be estimated and the gas consumption approximately determined.

STATION PIPING

All of the suction and discharge piping is contained in a concrete-lined pit, 6′ × 9′ 6″, running the length of the building. The relative location of mains is well shown in Figs. 9 and 10. The 36-inch suction main is of riveted steel plate, and extends to the river bulkhead. It is prevented from being drained by an automatic check valve, located in a capacious street manhole.

The discharge main is constructed of 21-inch special rolled steel pipe, ⅜ inch in thickness, with rolled steel flanges. The main terminates in a tee connecting with a riveted steel standpipe or "air chamber" which absorbs the shock due to the closing of the checks on any outside courses. From this tee the main discharge extends through the building to the street network. Cast steel angle nozzles are riveted to both suction and discharge mains for pump connections.

The upper or overflow main simply returns to the river the by-pass water during starting. It is not under pressure.

OPERATION

The supreme test of correct organisation of any plant of high character lies in its certain and efficient operation. In this instance the operation up to the present time seems to indicate sufficiency in design and organisation.

The training of the operating force has been along lines conducing to intelligent and energetic action, and was continued through six weeks prior to the official acceptance of the station. As a result the average time required for placing the entire station in service is sixty seconds per unit from the time of signal from fire headquarters. Of this, not more than forty-five seconds is ever consumed from the opening of the engine throttle to the loading of pumps to the required 300 pounds working pressure. The entire capacity of the station is then available within seven minutes from the signal, and the working pressure is available at hydrants within one minute. This result could hardly be accomplished with movable apparatus.

The station operating force consists of two men,—an engineer and assistant,—the entire station being under direct charge of a superintendent. Three eight-hour shifts constitute the working day. During the six weeks' training these six operatives ran regular daily shifts of three hours each, Sundays excepted. During each shift the alarm was sounded without warning, and several units were gotten under way.

No complete official tests of the station and high-pressure system have been made up to the present time. Unofficial tests have, however, indicated that expectations have been realised, and the results of operation of the system up to the present time show that an abundance

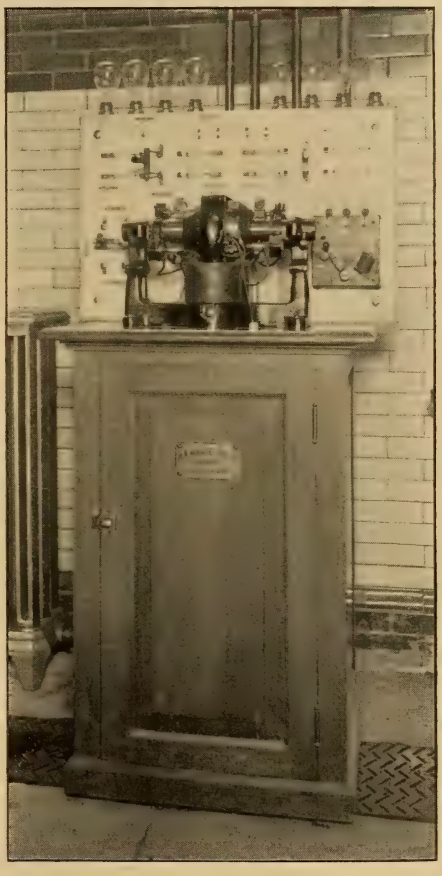


FIG. 14.—ONE OF THE IGNITER CABINETS

of propulsive force is now available within unprecedented time.

The execution of the work of establishing the high-pressure fire service system was accomplished by the Bureau of Water, a sub-department of the Department of Public Works of Philadelphia, under the management of Chief of Bureau F. L. Hand. The pumping station and the service system are operated by the Bureau of Fire,—a sub-department of the Department of Public Safety.

The pumping station was officially accepted by the Philadelphia Bureau of Water, at the close of 1903, from Messrs. M. R. Mucklè, Jr., & Co., engineers, of Philadelphia, who designed and installed the entire power equipment of the plant. The engineering details and design of the building were executed by Mr. John E. Codman, chief draughtsman of the Bureau of Water, and carried out by Mr. J. W. Weaver, superintendent. It was thus by the co-operation between the chief engineer, his assistants and the contractors that a harmonious result has been secured and success attained in an enterprise presenting some of the most radical departures from modern power station practice.

ELECTRIC POWER IN BRITISH SHIPYARDS

WITH SPECIAL REFERENCE TO THE NORTH-EAST COAST

By C. S. Vesey Brown, M. Inst. C. E.

AMONG the many industries congregated around the districts of the rivers Tyne, Wear, and Tees, there are none which have made such rapid strides in the last few years in the application of electric power as that of shipbuilding. It is safe to say that in 1894 there was not an electric motor at work in any of the shipyards in the district for the purpose of driving the tools used in shipbuilding, and possibly beyond a few motors used for cranes, and dynamos for lighting, there was not any electrical apparatus in regular use. In 1904 the situation is entirely reversed, and, with very few exceptions, there is not a single shipyard which does not derive either the whole or a very considerable portion of its power from electricity.

The transition from steam to electricity has been carried out in the face of a period of considerable activity in the trade, practically without any interruption in the work in hand, and advantage was taken of whatever temporary labour troubles there were to complete the transformation, for shipbuilders having once realised the immense advantages which electrical driving presented, were not slow to avail themselves of the opportunity to adopt it. The experience which has been gained by the change from steam to electric driving has shown how very wasteful were the long lines of steam pipes and the many small engines scattered about the shipyards, as for the most part the steam plant consisted of isolated banks of boilers, each with its separate staff and all the paraphernalia of separate coaling and water systems. After the old engines had been all displaced by motors driven from one central station the economies were found to be almost phenomenal.

It is significant of this experience that at the present time whenever a new tool is required or any alteration has to be made in the arrangement of a yard, there is no question as to what motive power shall be used, but rather how much can the electrical distributing system be improved and how far can any new tool be altered from steam, hydraulic or compressed air to electrical driving. In the majority of cases the original equipment of the plant was carried out with an eye to the future arrangements, but those installations put down in the period from 1894 to 1897 have had, of necessity, to be remodelled in order to keep pace with the electric power progress and to obtain the full benefit of the experience of the past ten years, and such reorganisation is taking place at the present time in several well-known yards.

It is difficult to give any comparative figures as to the relative costs of the old steam power and the newer electric installations, owing principally to the fact that as soon as shipbuilders realised the great advantages which electricity gave them to increase their output they added machines as fast as it was possible to put them down to carry on and extend their business. From figures supplied by a shipbuilding firm who adopted electric driving in its early stages, it is possible to give a comparison of the cost of power per "pound of wages paid" in the years 1894 and 1901, that is to say, before and after the use of electric-

FIG. 1.—PUNCH, SHEARS, AND ANGLE CUTTER, MADE BY MESSRS. A. & P. W. MCONIE, OF GLASGOW, IN THE SHIPYARD OF MESSRS. FURNESS, WITHY & CO., LTD., HARTLEPOOL

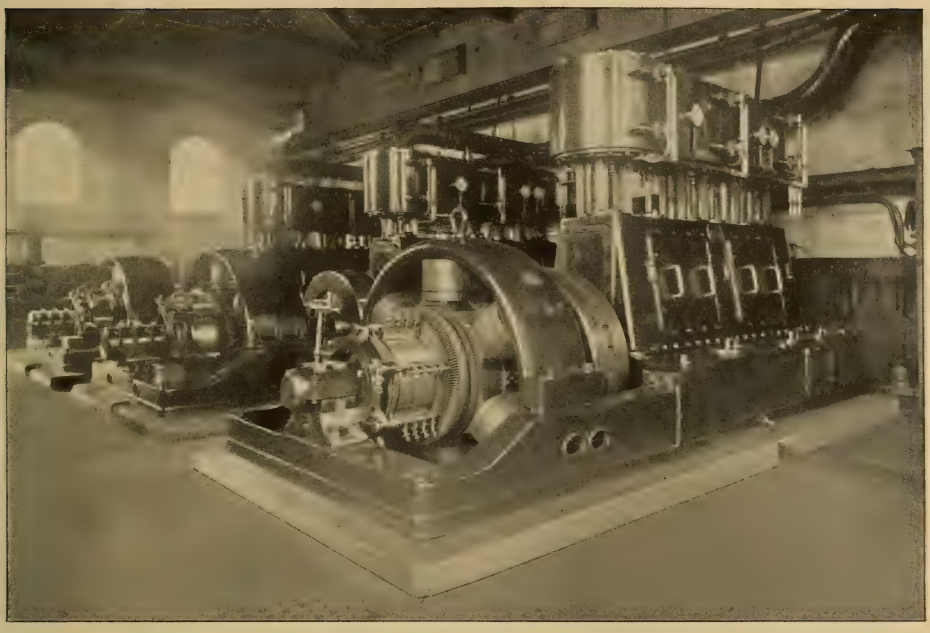


FIG. 2.—GENERATING PLANT AT MESSRS. W. T. DOXFORD & SONS' YARD. ENGINES BUILT BY THE SUNDERLAND FORGE & ENGINEERING CO., LTD., OF SUNDERLAND, AND DYNAMOS BY THE SAME FIRM AND ALSO MESSRS. J. P. HALL & CO., LTD., OLDHAM

ity. The figures are as follows :— In 1894 the cost for coal, gas and labour for driving the engines scattered round the yard was 8.66 pence per "pound of wages paid," and in 1901 the cost for coal, labour and other incidentals for producing the power electrically was 4.88 pence per "pound of wages paid," or, in other words, the wages paid in 1901 were practically double those paid in 1894, and the cost for power was the same, and this in spite of a very great increase in the number and size of the machine tools employed, which, in the yard in question, practically amounted in 1901 to six times what were in use in 1894.

The cost of producing a Board of Trade unit varies from slightly under a penny to a penny farthing, depending on the load factor, the area of distribution and the size of the plant. These figures of cost include an allowance of 10 per cent. for interest and depreciation on the generating plant and distributing cables.

The general reduction in the cost of power has enabled the shipbuilder to cope with the increase in the size and the extra fitting out of ships in the present day as compared with what was required, say, ten years ago. In one case, brought to the writer's notice, it appears that the average size of ship turned out by a certain yard in 1894 was 315 feet length by 40 feet beam, while in 1902 the average size had gone up to 475 feet length and 56 feet beam, and the indications are all in favour of this average being considerably increased in the near future.

In addition to the increase in the size of ship, there are other and more onerous conditions which rule in shipbuilding in 1904 as compared with 1894, such as the provision for better passenger accommodation, more efficient cargo-handling equipment, facilities for the carriage of cattle, petroleum, etc., and these requirements have all increased the cost of production in shipbuilding, so that in 1902 the tonnage turned out per man employed in the same yard has fallen to an average of 24¾ tons, as against 26½ tons in 1894.

One of the consequences and advant-

FIG. 3.—PUNCH AND SHEARS MADE BY MESSRS. A. & W. SMITH & CO., LTD., GLASGOW. DRIVEN BY A BRITISH THOMSON-HOUSTON COMPANY 10 H. P. THREE-PHASE MOTOR AT 400 VOLTS. THE NORTHUMBERLAND SHIPBUILDING COMPANY'S YARD AT WILLINGTON-ON-TYNE

ages of the adoption of electric power has been the concentration of all the generating plant into one building, with facilities, due to the proximity of the rivers, for condensing the exhaust steam and the supply of a cheaper class of fuel than had been used before in the isolated boiler plants. Naturally the labour bill, too, was greatly reduced. As the result of experience it is found that rarely more than 66 per cent. of the nominal horse-power of motors installed has to be supplied from the generating plant, so that, in designing any extensions of plant, distributing system or motors, the shipbuilder can with very fair accuracy calculate what will be required in either of these sections of his electrical department.

In the course of the investigations which were made for the purposes of this article it was found that there was considerable diversity of practice as regards the electrical systems in use. The electrically equipped yards can be roughly divided into three sections, namely, those in which 125-volt continuous current is employed; others where the pressure was either 220 or 250 volts, with continuous current; and the very latest installations, where three-phase alternating current at 400 to 440 volts is used.

FIG. 4.—A VIEW OF THE OVERHEAD EQUIPMENT IN THE YARD OF MESSRS. FURNESS, WITHY & CO., LTD.

The first-mentioned represent the earlier installations. Examples of these are found at the yards of Messrs. Furness, Withy & Co. and Messrs. Swan & Hunter. As confidence in the use of the power was instilled into the minds of the heads of the shipbuilding industry, and the practice in what was then high-voltage, continuous-current work became more perfect, later installations were put down to work at 220 or 250

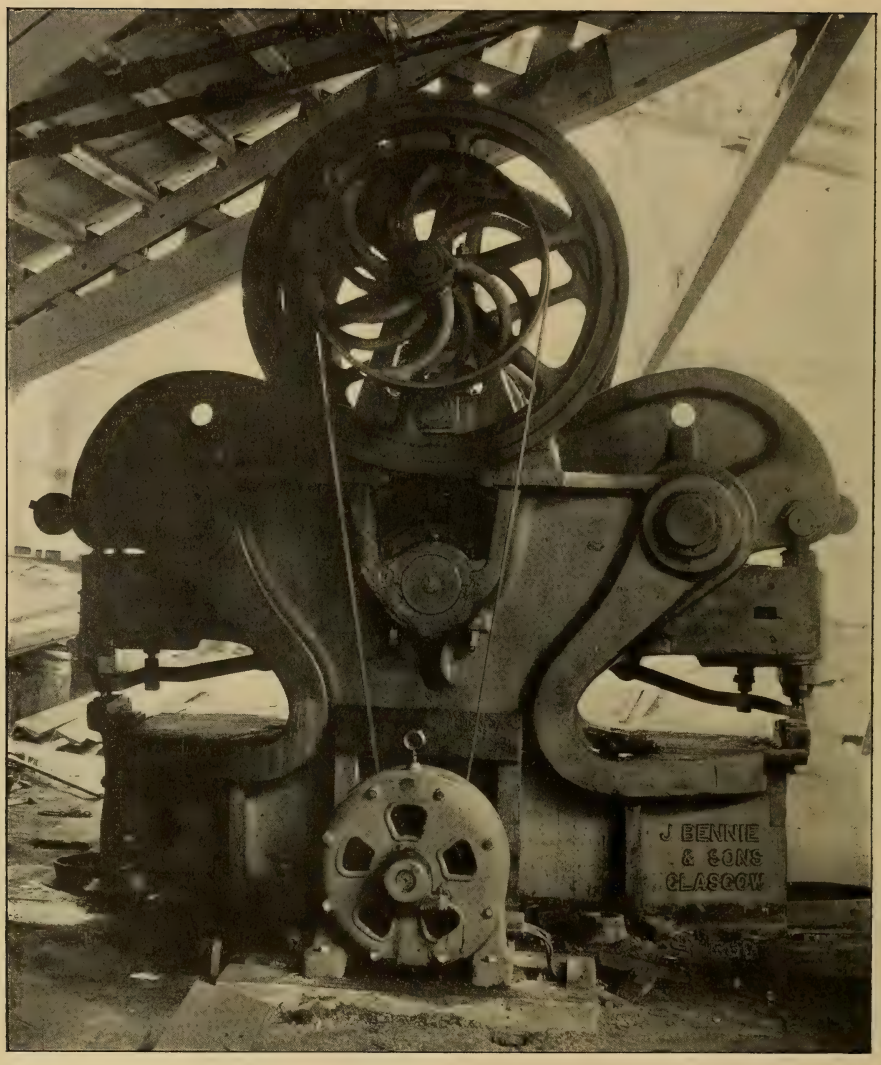


FIG. 5.—A DOUBLE PUNCH DRIVEN BY A BRITISH THOMSON HOUSTON COMPANY 10 H. P. THREE-PHASE MOTOR AT THE YARD OF SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD., WALKER ON-TYNE

volts, and then, with the advent of the three-phase alternating-current experience from the Continent of Europe and America, this type of installation was adopted as being the very latest and most up-to-date system of distribution. Examples of the 220-volt, continuous-current work are to be seen, amongst others, at the yards of Messrs. W. T. Doxford & Sons and Messrs. R. Stephenson & Co., and of three-phase work at the yards of Messrs. Armstrong, Whitworth & Co., Ltd., Palmer's Shipbuilding & Engineering Company, Ltd., Messrs. Hawthorn, Leslie & Co., Ltd., and the Northumberland Shipbuilding Company, Ltd., all on the river Tyne.

Since the supply of power has been available from the Neptune Bank station of the Newcastle-upon-Tyne Electric Supply Company, Ltd., the use of three-phase alternating current has been more general, and has so far proved a success, as a considerable number of power users

have taken this company's supply at prices which compare favourably with what it would cost the shipbuilder to generate his own supply after making due allowance for interest and depreciation.

There is some advantage in the use of three-phase current over the continuous-current system, especially if a higher pressure than 250 volts be required, in view of the difficulty of lighting the offices from a two-wire, continuous-current system at a higher pressure than 250 volts; but on the score of simplicity there does not appear to be any advantage on one side or the other, and though the question of maintenance naturally arises, as far as could be gathered from works where continuous current has been in use from eight to nine years, the continuous-current plant requires only a small amount of attention to the commutators and brushes. The principal repairs in each case are in connection with the starting switches and regulating apparatus, which seem to be the weak points on both the continuous and the alternating-current systems.

In the majority of cases the power plants are owned and operated by the firm who own the shipyard; but, as has already been stated, there are a number of yards along the north side of the Tyne which take power from the Newcastle Electric Supply Company's power station. The yard of Messrs. Swan & Hunter is a notable exception to this, as the power plant in this case was erected in 1895, and is now being remodelled to deal with extensive alterations in the yard and to take advantage of the electric experience gained since that date.

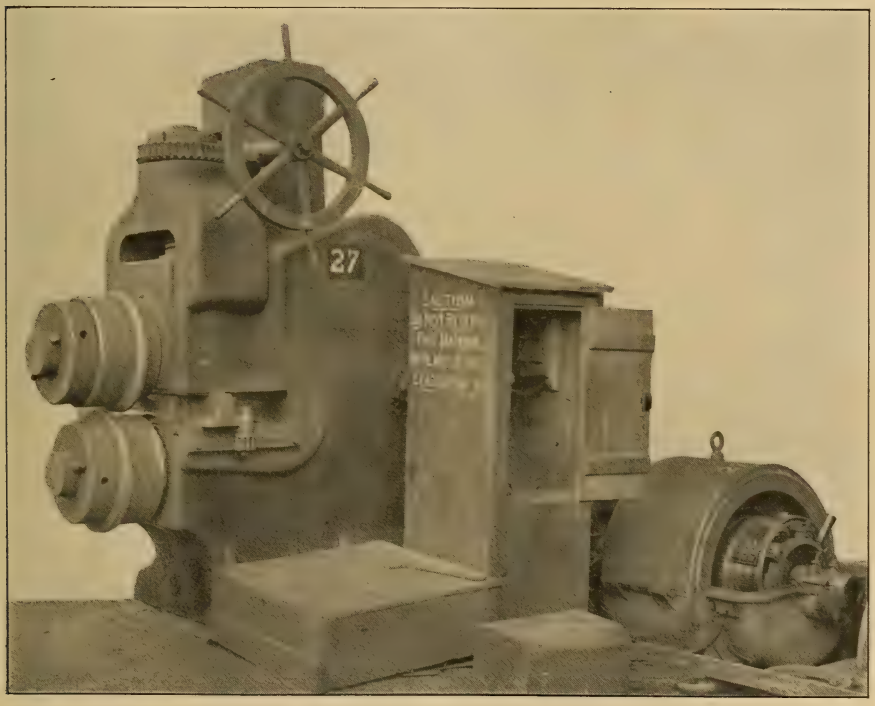


FIG. 6.—DOXFORD'S JOGGLING MACHINE, BUILT BY MESSRS. FRANCIS BERRY & SONS, SOWERBY BRIDGE, DRIVEN BY A 25 H. P. CONTINUOUS-CURRENT MOTOR MADE BY THE SUNDERLAND FORGE & ENGINEERING CO., LTD.

The continuous current-power plants, as a rule, consist of marine-type boilers and high-speed steam engines directly coupled to continuous-current, shunt-

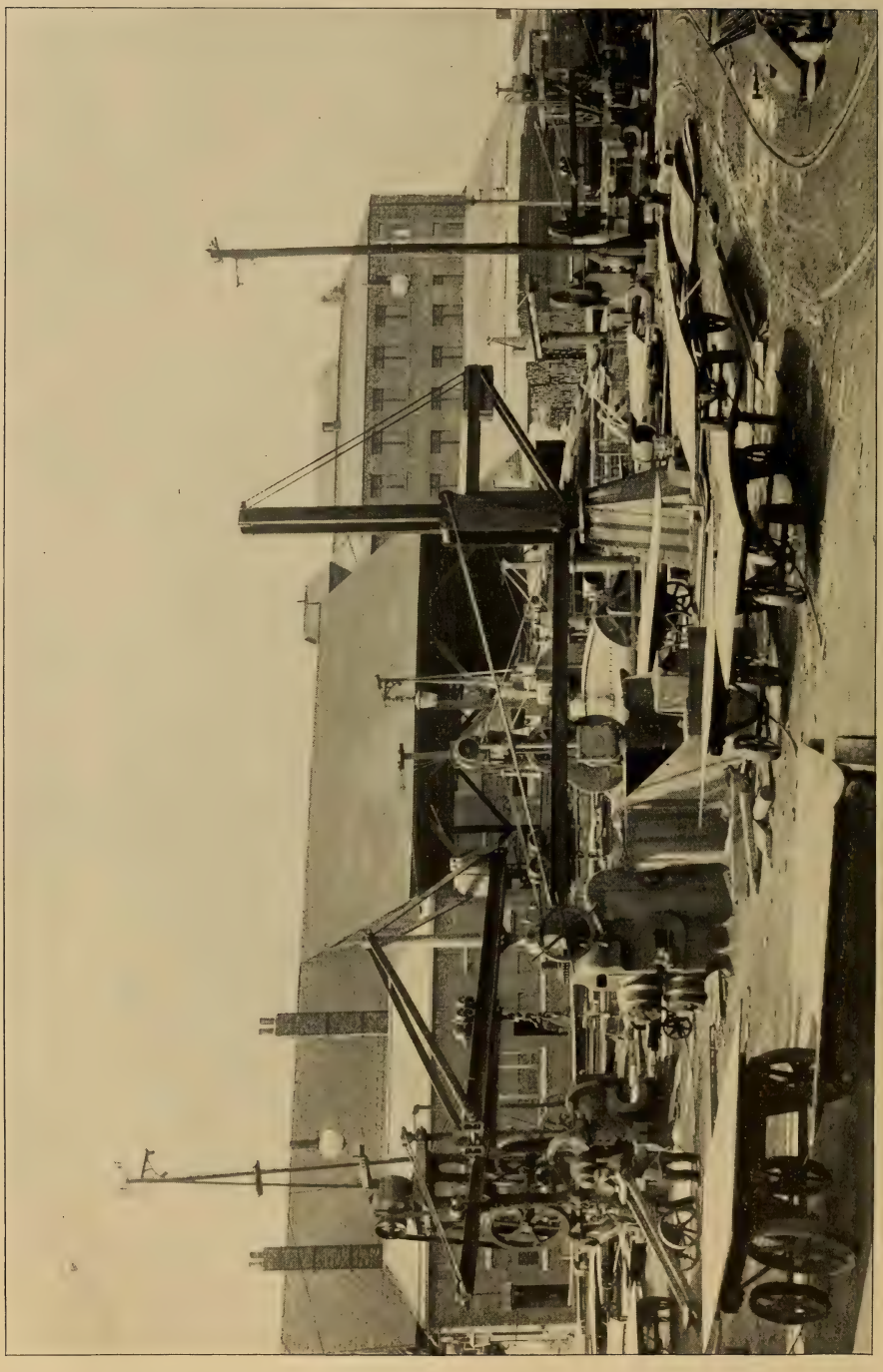


FIG. 7.—A CORNER IN THE YARD OF MESSRS. W. T. DOXFORD & SONS, AT PALLION, SUNDERLAND, SEVERAL ELECTRICALLY DRIVEN TOOLS ARE HERE SHOWN

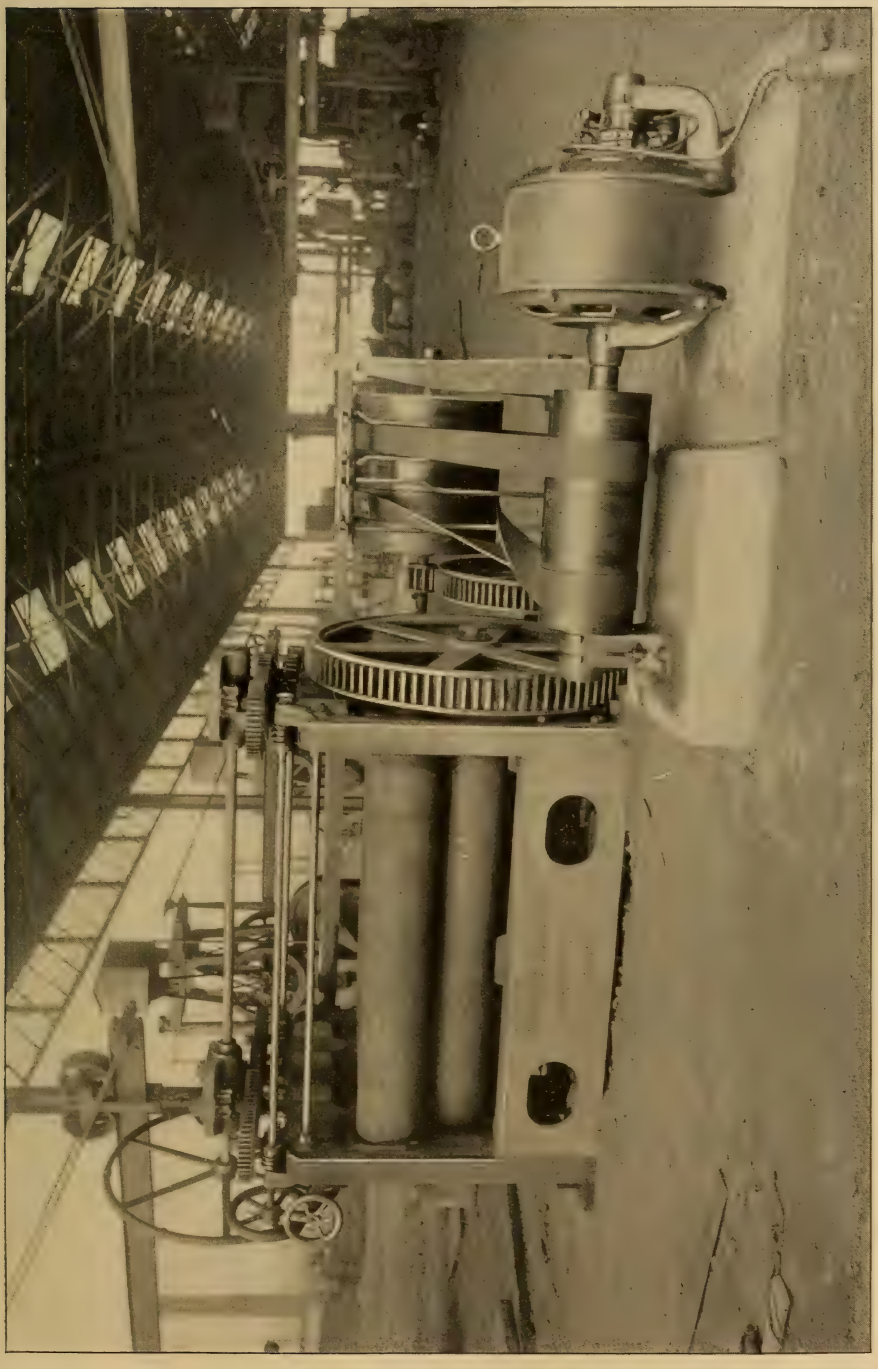


FIG. 8.—PLATE-STRAIGHTENING ROLLS, BUILT BY MESSRS. CRAIG & DONALD, JOHNSTONE, NEAR GLASGOW, SCOTLAND, DRIVEN BY A 13 H. P. CONTINUOUS-CURRENT MOTOR AT 250 VOLTS. INSTALLED IN THE SHIPYARD OF MESSRS. R. STEPHENSON & CO., LTD., HEPBURN-ON-TYNE, BY MESSRS. WARREN, BEATTIE & CO., LTD., MIDDLESBORO

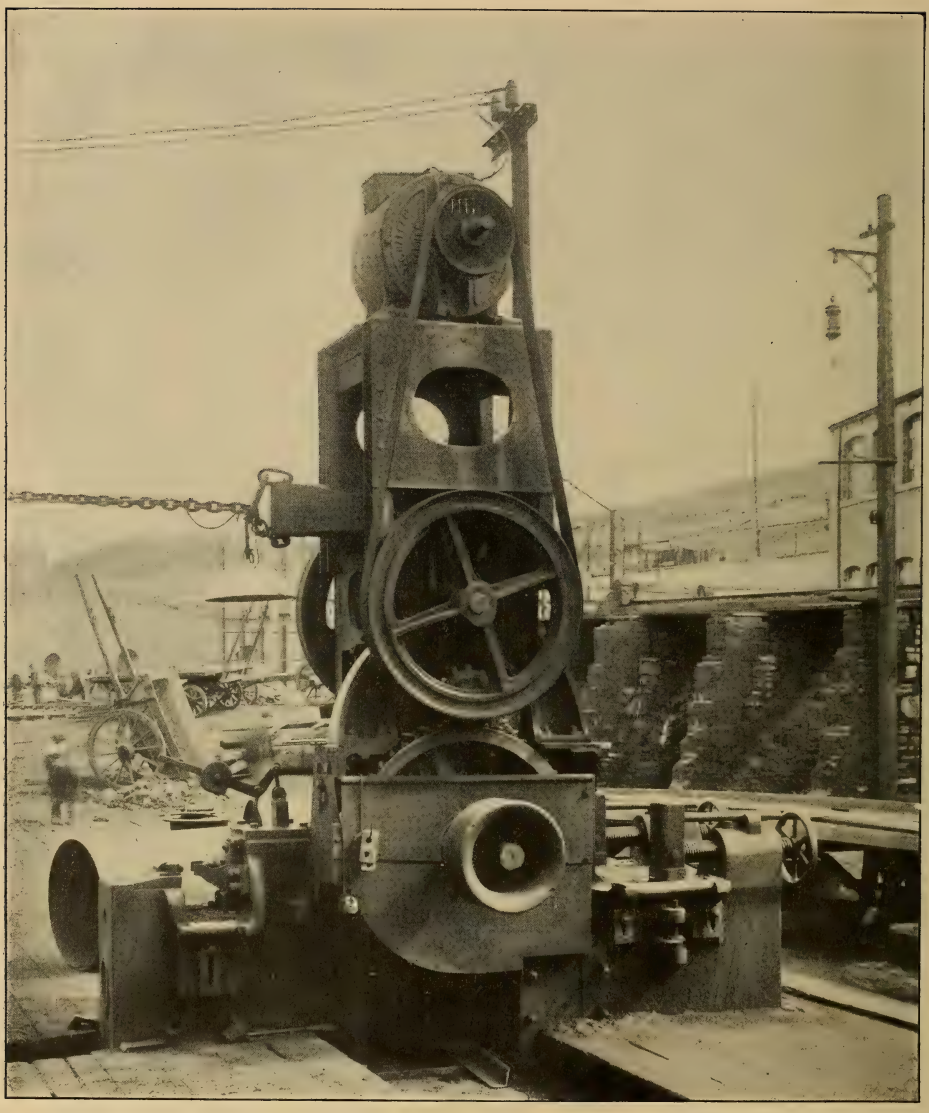


FIG. 9.—HORIZONTAL ANGLE PUNCH, BEAM BENDER AND STRAIGHTENER, AND WINCH, DRIVEN BY A J. P. HALL & CO. 15 H. P. CONTINUOUS-CURRENT MOTOR AT 220 VOLTS, AT THE YARDS OF MESSRS. W. T. DOXFORD & SONS, PALLION, SUNDERLAND

wound dynamos. One of the older installations,—that at the yard of Messrs. Furness, Withy & Co.,—shows that there are still a few belt-driven plants which have done good service and compare favourably with the more modern high-speed steam dynamo.

In using shunt-wound dynamos, no trouble has been experienced with any fluctuations in the pressure of supply sufficient to affect the lighting system, which is always supplied from the same machine furnishing power to the motors. It is natural that lighting should form a considerable portion of the load. Inverted arc lamps are extensively used in the draughting rooms.

Overhead transmission lines are uni-

versally used, and consist, for the most part, of rubber-insulated cables attached to porcelain insulators, which are, in turn, fixed to wooden cross-arms on wooden poles. A good example of this work is shown in Fig. 4.

Probably the earliest example of the actual application of electricity to drive shipyard tools in the district was at Messrs. Furness, Withy & Co.'s yard, at Hartlepool, and a short account of this installation will, therefore, not be out of place as showing from what small beginnings the installation of electric power began and what were the remarkable results of a very interesting experiment. Scattered around the building berths in the yard were a number of steam winches used in conjunction with derricks to hoist and hold up the plates, angle bars and other material required in building ships. These winches took steam from the same boilers that supplied a shop engine of about 70 H. P., used for driving miscellaneous machine tools, and it was a common experience that whenever the winches were used, the shop engine could not get enough steam and often was nearly brought to a standstill.

It was suggested to Mr. Withy that, to overcome this defect, he should try the experiment of putting electric motors on the winches and supplying them with power from a dynamo driven by the aforesaid shop engine. This was done. A 50 H. P. dynamo was belted on to the same shafting as the machine tools, and motors were fitted to the five winches, with a belt-drive through countershafting on each. The remarkable result of this experiment was that the shop engine supplied the power to the winches and at the same time to the machine tools already coupled to it, and one boiler less was used than formerly!

With such a striking example before them of the effect of electric driving, it is not surprising that the firm decided to extend the use of the power, with the result that to-day all the tools at this yard are run by electric motors supplied from two steam dynamos of 300 H. P. each. The plant for supplying the

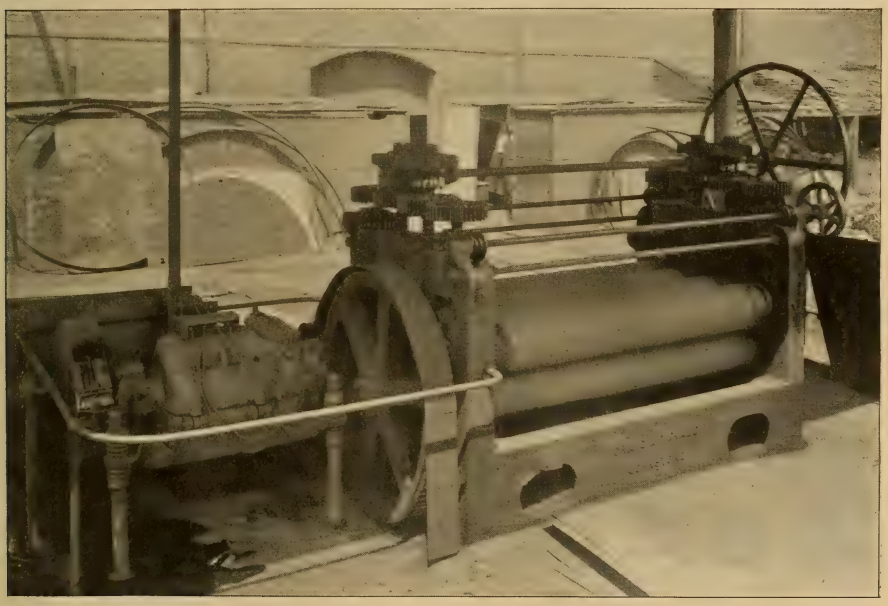


FIG. 10.—PLATE-STRAIGHTENING ROLLS, MADE BY MESSRS. CRAIG & DONALD, LTD., JOHNSTONE, DRIVEN BY A BRITISH THOMSON HOUSTON COMPANY DIRECT-GEARED RAILWAY TYPE MOTOR AT THE WORKS OF THE NORTH-EASTERN MARINE ENGINEERING CO., LTD., WALLSEND

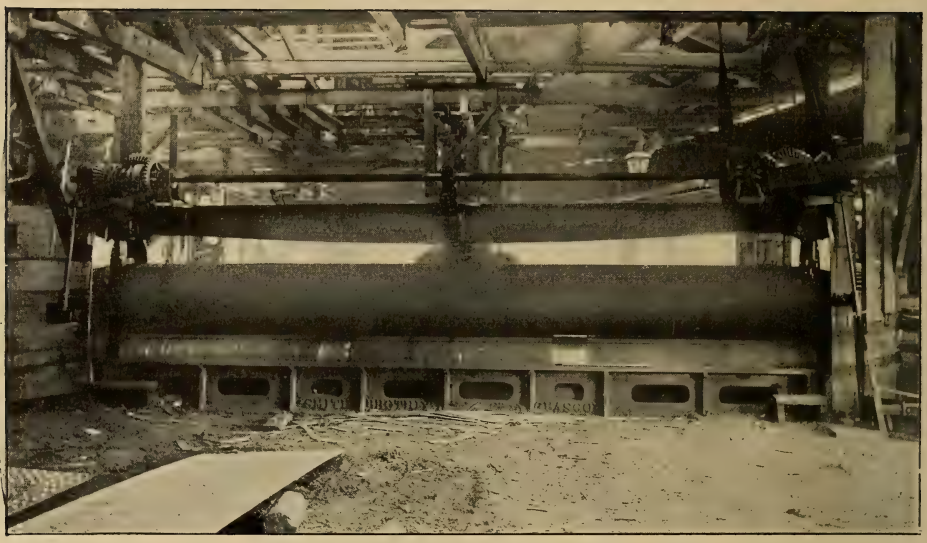


FIG. 11.—ROLLS FOR HEAVY SHIP PLATES AT THE YARD OF MESSRS. FURNESS, WITHY & CO., AT HARTLEPOOL, DRIVEN BY ONE OF THEIR 40 H. P. CONTINUOUS-CURRENT MOTORS

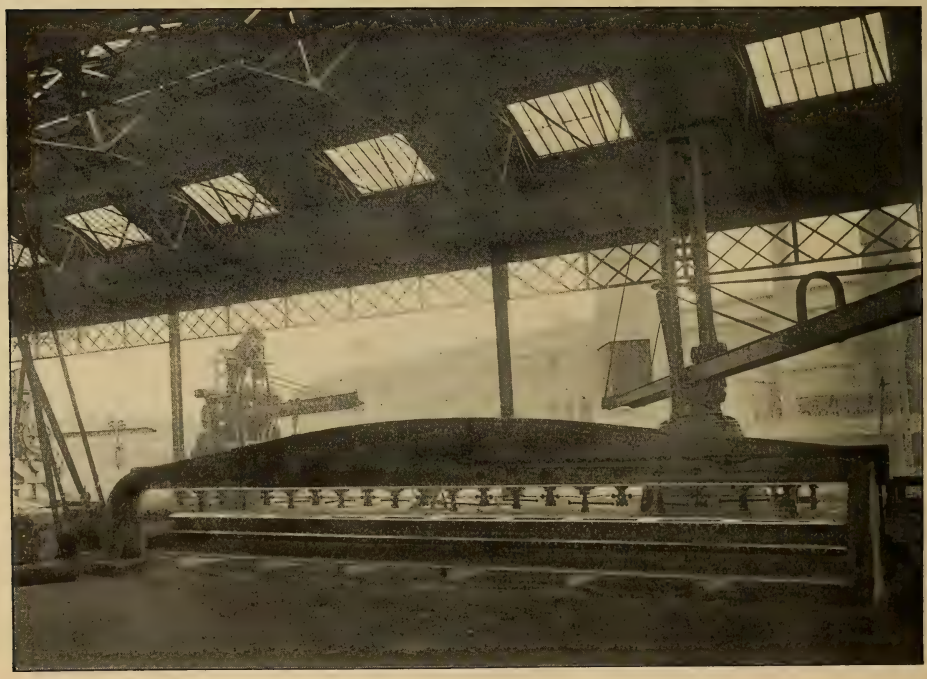


FIG. 12.—A 30-FOOT PLATE EDGE PLANER IN THE YARD OF MESSRS. R. STEPHENSON & CO., HEPBURN-ON-TYNE, DRIVEN BY A 15 H. P. CONTINUOUS-CURRENT MOTOR AT 250 VOLTS

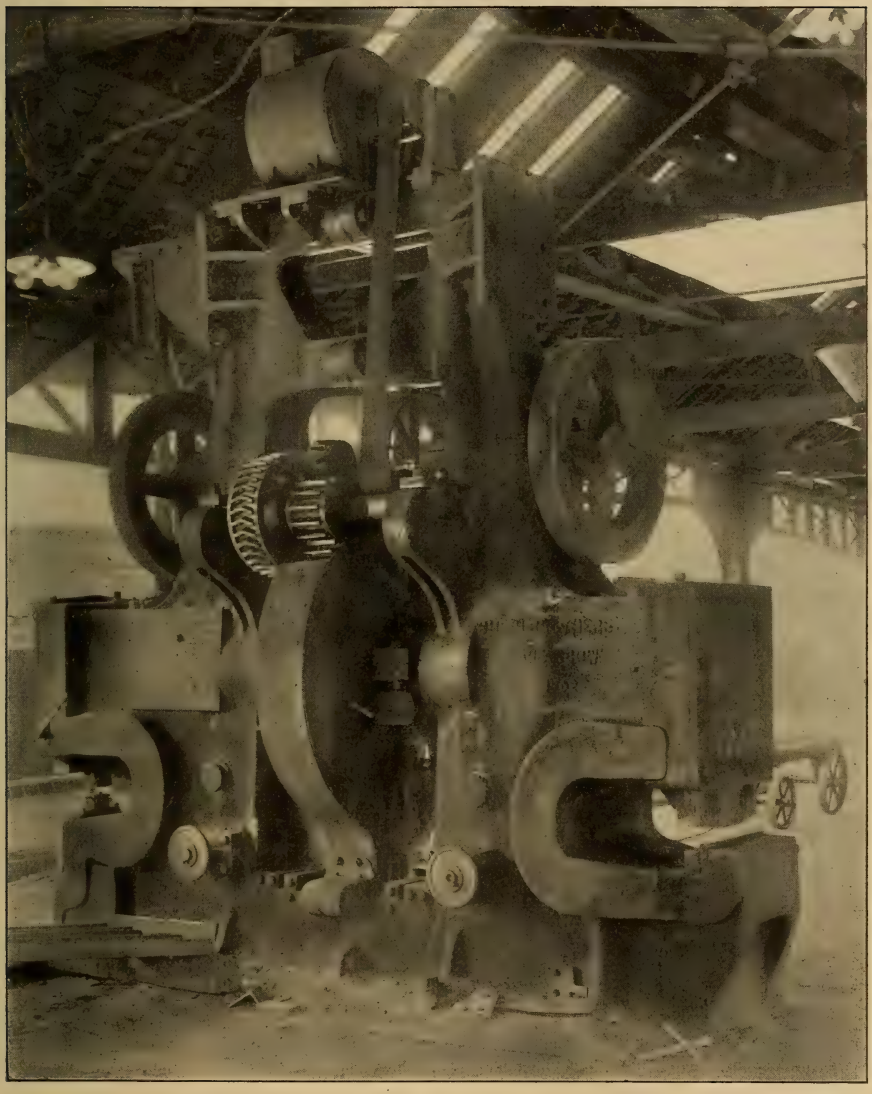


FIG. 13.—PUNCH, SHEARS AND DOUBLE-ANGLE CUTTER MADE BY MESSRS. SMITH BROTHERS, GLASGOW, DRIVEN BY A J. P. HALL & CO. 15 H. P. CONTINUOUS-CURRENT MOTOR AT 220 VOLTS AT THE YARD OF MESSRS. W. T. DOXFORD & SONS

power consists of a marine type Westgarth-English engine driving two Pieper dynamos by belt and an Anderson Foundry Company's direct-coupled steam dynamo, both engines being supplied with steam from two marine boilers. With the exception of the dock pumps and a large crane, both close to the boiler room, there is not a single steam engine in the yard, and even the hydraulic accumulator pumps are driven electrically.

As previously stated, the increasing requirements for fitting out ships were becoming more onerous, and it was at an opportune time that the application of electric driving enabled the firm to deal with the many problems involved in the extra work in their own yard instead of purchasing from other makers.

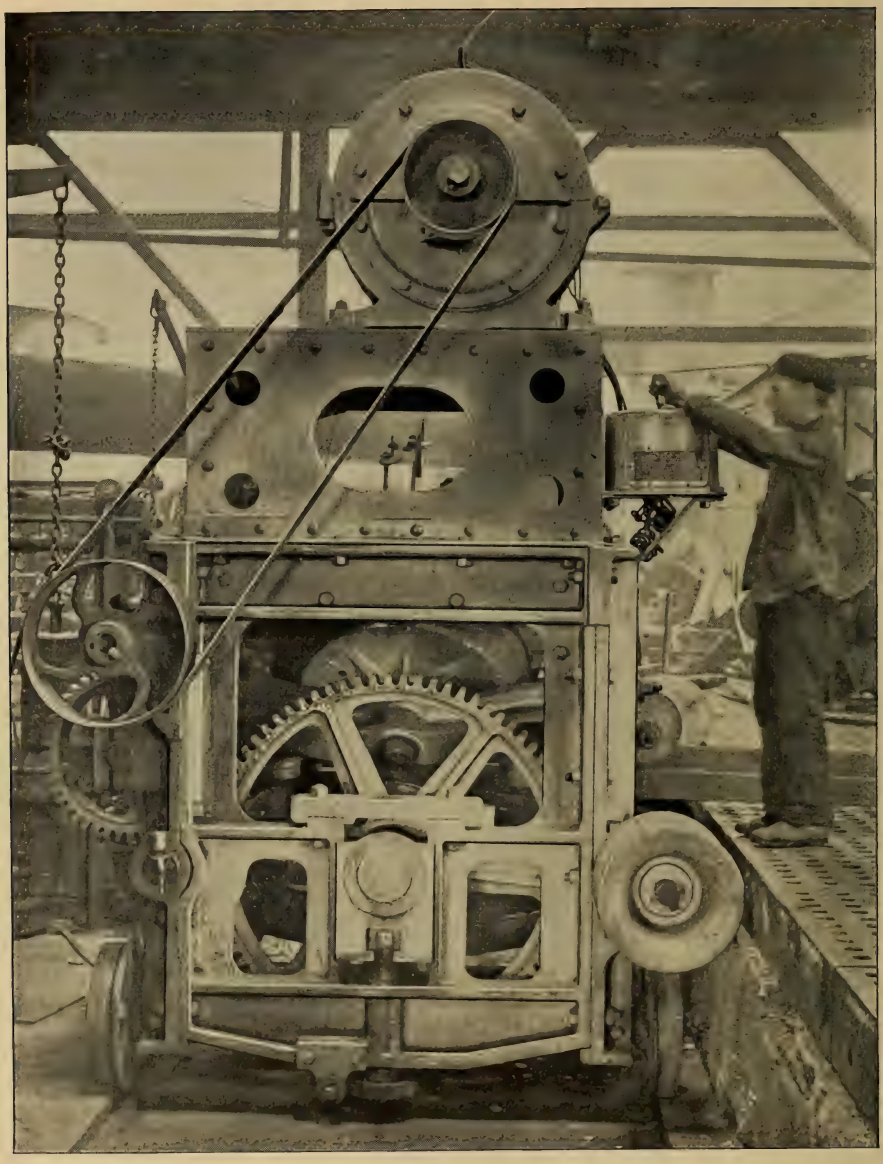


FIG. 14.—ANGLE BAR BEVELLING MACHINE, MADE BY MESSRS. DAVIS & PRIMROSE, EDINBURGH, AT THE YARD OF MESSRS. J. L. THOMPSON & SONS, SUNDERLAND. DRIVEN BY A 10 H. P. CONTINUOUS-CURRENT MOTOR AT 220 VOLTS, MADE BY THE SUNDERLAND FORGE & ENGINEERING CO., LTD., PALLION, SUNDERLAND

As an example of what was done it may be mentioned that a department was established for attending to the many motors in the yard, and this very soon became a manufacturing department for dynamos and motors for the firm's own requirements in the yard. But in time it spread to the supply of wiring for the ships built by the firm and for the small steam dynamos required to light these ships. Each little steam dynamo bears a brass label stating that it has been

"tested for 100 hours under full load," a remarkable achievement for a shipbuilding firm to accomplish in such a comparatively short space of time, and which to a large extent is due to the facilities for manufacturing afforded by the use of electrical power.

Other appliances, such as ash hoists, operated by small electric motors, small bilge pumps, etc., are made by the firm

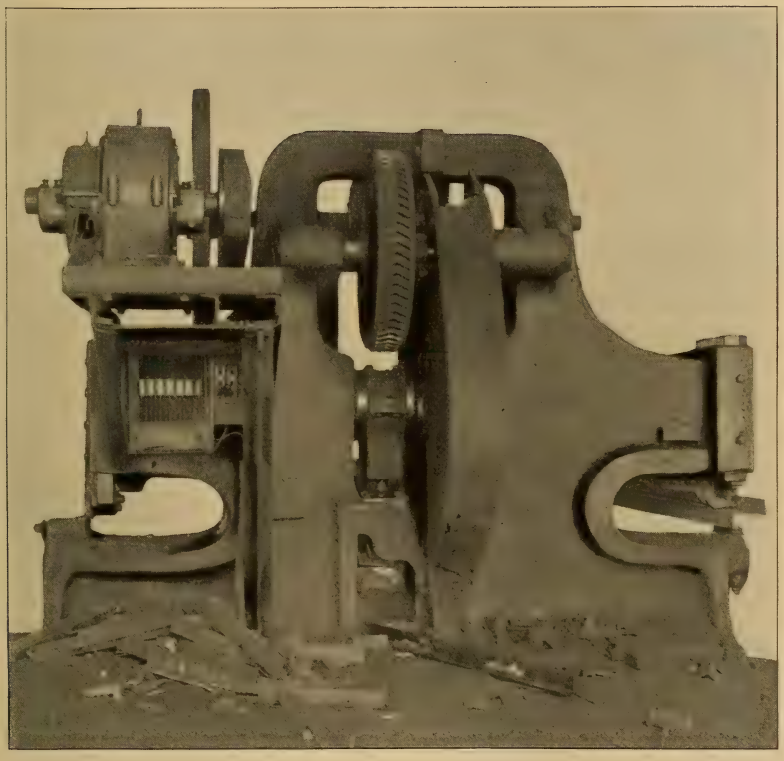


FIG. 15.—PUNCH, SHEARS AND ANGLE CUTTER AT THE YARD OF MESSRS. J. L. THOMPSON & SONS, NORTH SANDS, SUNDERLAND. DRIVEN BY A 10 H. P. CONTINUOUS-CURRENT MOTOR, MADE BY THE SUNDERLAND FORGE & ENGINEERING CO., LTD.

in the same manner and as the result of the facilities above mentioned, and though it is not the intention of this article to describe in detail the manufactures of any one firm, yet the above will serve to show how easily the characteristics of a shipbuilding firm may be altered by the change in the power for driving the machine tools; and when it is stated that, with the exception of the main engines and boilers, the cargo-handling equipment, and the steering gear, practically the whole outfit for an ordinary 10 to 11-knot steamer can be turned out from a shipyard which, up to a few years ago, dealt only with the hull, it will be acknowledged that a considerable change has been made for the better in the displacement of steam power by electricity, at any rate from the point of view of Messrs. Furness, Withy & Co.

The usual equipment of tools in a shipyard consists of punches, shears, plate rolls, winches and other hoisting gear, hydraulic plant, etc. In the majority of cases these tools are identical in design and are treated in the same manner as regards the driving arrangements; but there are a few cases of di-

versity of practice which it may not be out of place to mention. Punching and shearing tools naturally occupy the greater part of a shipyard's equipment, and are made up in all sorts of sizes and combinations to suit certain requirements, such as the provision of angle cutters on the same tool as a punch, and so on. As a general rule, about 10 H. P. are required per machine; but in some of the larger sizes 15 H. P. are necessary.

The machines are generally converted from steam to electricity by substituting for the engine a motor fixed on the top of the tool or on the ground, driving by belt on to a pulley fixed on a straight piece of shaft in place of the old crank-shaft of the engine. Figs. 1, 3, 5, 9 and 13 are all types of punches, shears and angle cutters which have been treated in this manner. Fig. 15 shows a similar tool made for driving through gearing, and gives a very good idea as to the method adopted for fixing the starting and regulating switches. The use of machine tools which have been designed for driving through gearing is becoming more frequent as the tool makers appreciate the advantages of making provision for electric motors on the frame of the tool.

Figs. 3 and 5 represent punches and shears driven by three-phase motors with current supplied from the Newcastle-on-Tyne Electric Supply Company's power station. Both illustrations are of tools which have been converted from steam to electricity. Fig. 7 is a very good view of the general manner in which the tools in a shipyard are grouped. In the centre is shown one of Messrs. Doxford's patent joggling machines, which were introduced when the firm commenced the turret type of steamer. Fig. 6 shows one of these tools coupled to a continuous-current motor made by the Sunderland Forge & Engineering Company, Ltd.

The mangling, rolling and straightening of plates form an important part of shipbuilding, and Figs. 8, 10 and 11 show good examples of different types of tools used for those purposes. Fig. 10 is particularly interesting as showing a novel method of applying the series type of tramway motor, suspended on springs in the same manner as under a tramcar.

Fig. 9 shows a type of machine for bending and straightening girders of different sizes up to 18-inch beams. To those not familiar with the numerous and varied combinations which shipyard machine tools are often designed to carry out, it will be seen how much time can be saved by providing at some convenient place a tool, like that shown in Fig. 13, which will straighten girders or angle irons, punch holes in these same irons, and, if necessary, bring them to the machine by means of the winch, all these operations being performed by the same motor.

Other machines illustrated show how the shipbuilder saves much space by combining the different tools in one machine. Fig. 14 shows a machine which is extensively used in all shipyards for giving the necessary bevel to the angle irons in all parts of a ship, and especially where the framework narrows at each end of the ship, so that the plates may lie flat on the surface of the framework. As a rule, the machine is placed on a small travelling bogie and run on a narrow-gauge tramway so that it may deal with the heated angle irons from any number of furnaces. The bars are drawn out of the heating furnaces and go straight into the machine, which has the necessary bevel wheels to give the angle iron or girder the required "set," and for which purpose an indicator, which can be seen through the hole in the frame supporting the motor, is provided. The starting and reversing controller can be seen at the side of the machine, and the brickwork of the heating furnace can be seen at the left of the machine. The bevelling machine here illustrated was made by Messrs. Davis & Primrose. Fig. 12 shows a 30-foot plate-edge planer, which is in use in all shipyards and is characteristic of similar machines used elsewhere.

(To be concluded in the April Number.)

MULTI-CYLINDER LOCOMOTIVES

A REVIEW OF THE WORLD'S PRACTICE IN MULTI-CYLINDER SIMPLE AND COMPOUND LOCOMOTIVES

By J. F. Gairns

PART IV.—MISCELLANEOUS FOUR-CYLINDER LOCOMOTIVES AND LOCOMOTIVES WITH MORE THAN FOUR CYLINDERS

Parts I., II. and III., dealing, respectively, with "Multi-Cylinder Simple Locomotives," "Three-Cylinder Compound Locomotives," and "Four-Cylinder Compound Locomotives," appeared in the issues for December, 1903, and January and February, 1904.

IN this section are included those multi-cylinder locomotives with four cylinders which could not properly be placed in any of the preceding sections, and also those engines which have more than four cylinders.

The divisions are as follows:—

1.—Combined Rack and Adhesion Locomotives (non-compound); 2.—Combined Rack and Adhesion Locomotives (compound); 3.—The Johnstone Eight-Cylinder Compound Locomotive; and 4.—Suggested Triple-Expansion Schemes.

1.—COMBINED RACK AND ADHESION LOCOMOTIVES, NON-COMPOUND

Rack railways are of two kinds. One is entirely separated from any other railway; the other works in connection with adhesion lines or forms a part thereof, the same engines working, or being capable of working, on both sections.

On railways of the first class the locomotives rely wholly upon the rack, so that no adhesion cylinders are needed, and, therefore, as these engines are comparatively small and draw light loads,

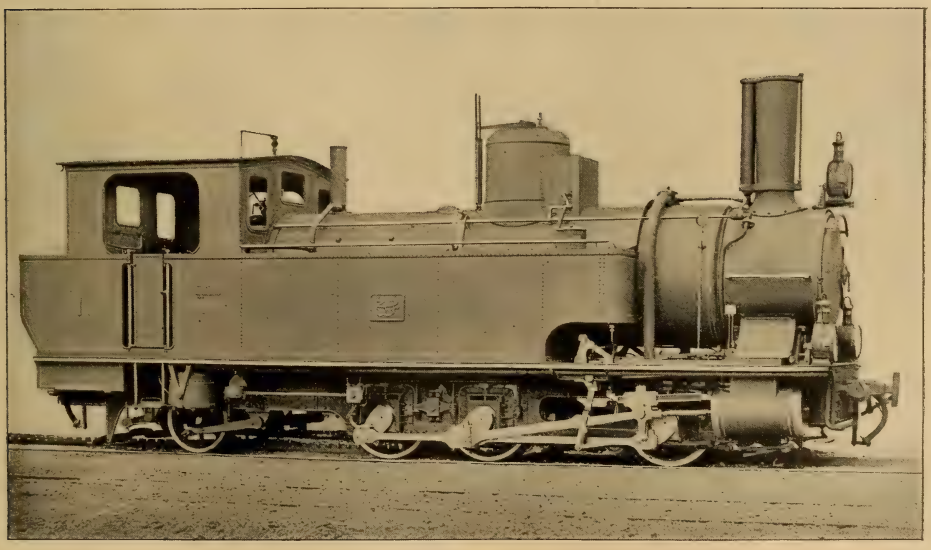


FIG. 61.—COMBINED RACK AND ADHESION LOCOMOTIVE BUILT BY THE SWISS LOCOMOTIVE WORKS, WINTERTHUR, FOR THE LEBANON, BEYROUT & DAMASCUS RAILWAY

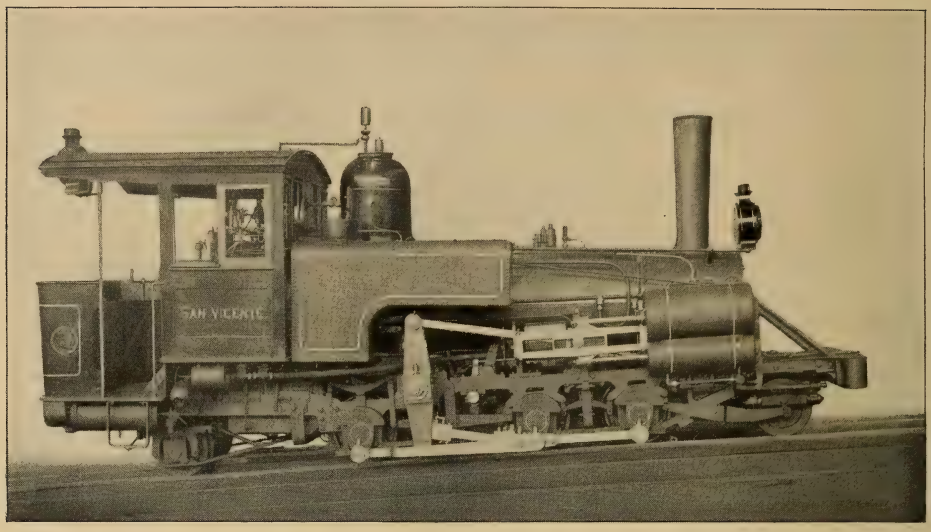


FIG. 64.—A VAUCLAIN COMPOUND RACK AND ADHESION LOCOMOTIVE BUILT BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA

though on heavy gradients, there are no multi-cylinder, non-compound engines.

In the second class, however, the provision of adhesion wheels, either to allow of shunting away from the rack, or for working regularly by adhesion on sections of the line, in many engines

FIG. 62

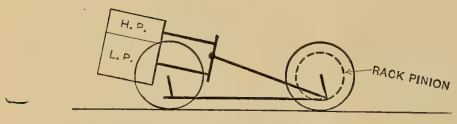


FIG. 63

causes the use of four cylinders, two for the rack pinions and two for the adhesion wheels, though it is a fairly usual practice, even with these engines, to use only the two cylinders and to provide clutches so that either the rack pinions or the adhesion wheels can be driven at will.

Fig. 61 illustrates an engine built by the Swiss Locomotive Works, of Winterthur. It has six-coupled wheels for adhesion work, driven by two outside cylinders, and there are two inside cylinders for actuating the rack pinions (see Fig. 62).

Many of these four-cylinder rack and adhesion locomotives, of various designs and dimensions, are in service.

2.—COMBINED ADHESION AND RACK LOCOMOTIVES, COMPOUND

Very little has been done with locomotives of this kind, for to use one set of cylinders with high-pressure steam and the other set with low-pressure steam is an impossible arrangement, as the two engines seldom or never work together, and the use of a high and a

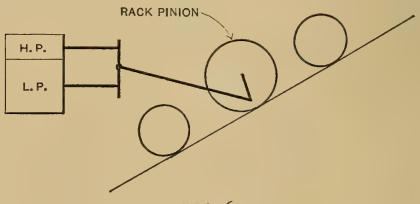


FIG. 65

low-pressure cylinder in each set is hardly worth considering on account of the nature of the work these engines do; but one compound system has been em-

ployed, the compound cylinders driving one or both sets of mechanism.

This system is the Vauclain, already described, and, indeed, it is probably the only system which will admit of this application, if only because of lack of space. On wholly rack lines, such as the Count Telfever Railway, in Italy, the Vauclain cylinders drive the rack pinions only as shown in Fig. 63. In other cases, the Vauclain cylinders drive the rack pinions, and can be coupled to the adhesion wheels when required. One of these engines, for the Cia Minera des Pinoles, is illustrated in Figs. 64 and 65.

In another design, which affords an example of a six-cylinder locomotive, there are three cylinders at each side, two Vauclain cylinders for driving the adhesion wheels, and a cylinder on top for driving the rack, as shown in Fig. 66.

Fig. 67 shows one of these engines, built for the San Domingo Improvement Company. From the illustration, it appears as if the leading wheels were driven from the rack cylinders; but this is not so, the wheels being loose on the rack shaft.

3.—THE JOHNSTONE EIGHT-CYLINDER COMPOUND LOCOMOTIVE

This locomotive represents, probably, the strangest class ever designed, excepting, perhaps, some of the out-and-out freaks which have at various times been put upon the rails. Reference has been made in earlier sections of this series of articles to Mr. F. W. Johnstone's "tender-motor" engine, and to his annular compound system as applied to more ordinary locomotives. The engines now under notice represent further developments, the object being to produce an engine for freight service capable of working on 3 per cent. grades and over 18-degree curves (22 degrees in sidings), and to do work which previously required "double heading."

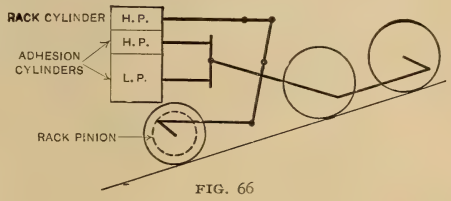


FIG. 66

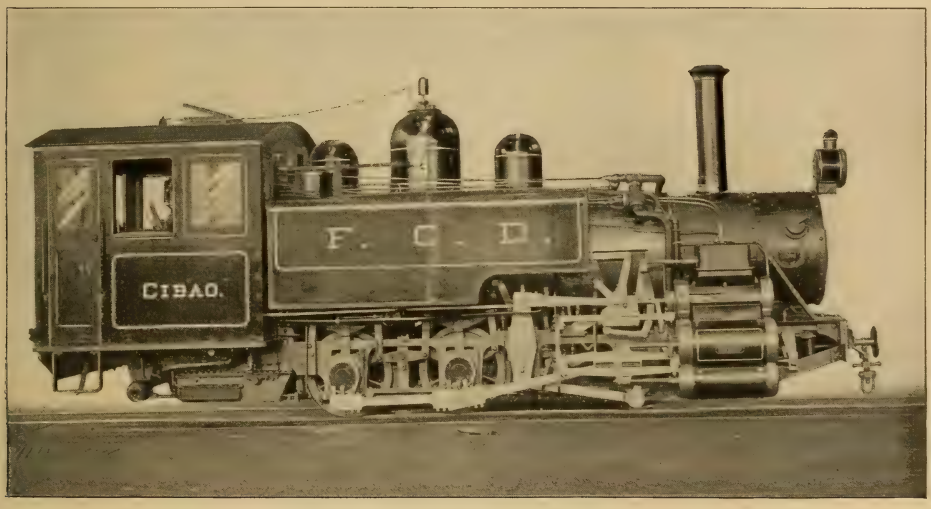


FIG. 67.—VAUCLAIN COMPOUND RACK AND ADHESION LOCOMOTIVE, WITH SIX CYLINDERS, BUILT BY THE BALDWIN LOCOMOTIVE WORKS, OF PHILADELPHIA, FOR THE SAN DOMINGO IMPROVEMENT COMPANY

Three of these engines were built in

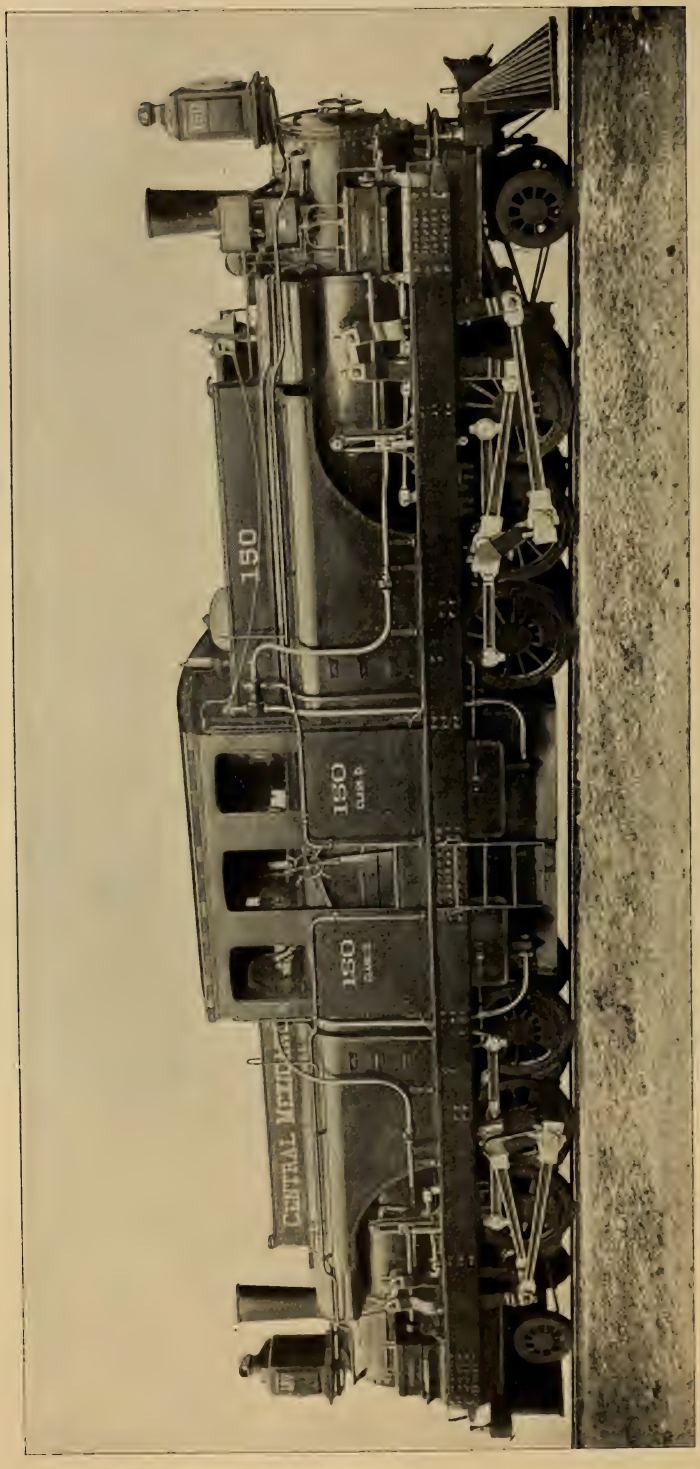


FIG. 68.—A JOHNSTONE ANNULAR COMPOUND DOUBLE-BOGIE LOCOMOTIVE WITH EIGHT CYLINDERS, ON THE MEXICAN CENTRAL RAILROAD. BUILT BY THE AMERICAN LOCOMOTIVE COMPANY

1892 by the Rhode Island Locomotive Works for the Mexican Central Railroad. As will be seen from Fig. 68, there are two sets of six-coupled wheels set in bogie frames, leading and trailing pony trucks, and two connected boilers set on a rigid frame, water being carried in saddle tanks over the boilers, and fuel in bunkers fitted on the frame.

The cylinders are fixed upon the frame, not on the bogies, and there are eight of them, four upon each part of the engine, there being a high-pressure cylinder and an annular low-pressure cylinder disposed round it at each side of the engine at each end. Each low-pressure piston has two piston rods, and these and the corresponding high-pressure piston rod are connected to one crosshead.

To connect with the wheels an ingenious arrangement of mechanism is employed. Each crosshead is pivoted to a lever *a*, Fig. 69, to the lower end of which one connecting-rod is attached,

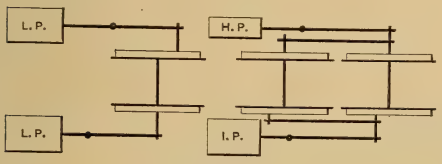


FIG. 70

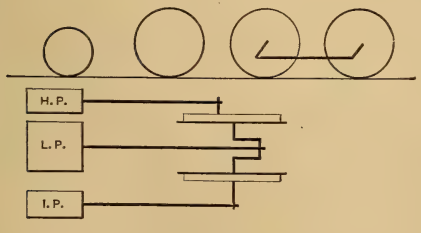


FIG. 71

while to the upper end a link is pivoted by which a lever *b*, fulcrumed at *c* on the frame, is driven, the other connecting-rod being driven by the lever *b*. Thus the wheels are driven by double connecting-rods acting at angles of 180 degrees. By this arrangement an equable turning effect is obtained, and also any tendency for the bogie to twist upon its centre is counteracted. Further, though this is not very clear, the

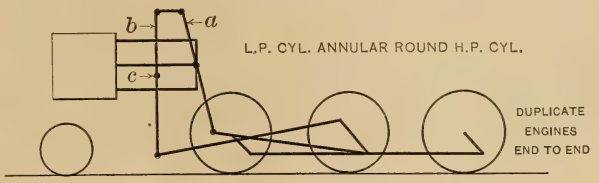


FIG. 69

bogie wheels are driven on curves whatever the relative positions of wheels and cylinders.

In work these engines are said to have given very good results, but no more of them have been built, nor have any locomotives compounded upon the Johnstone system been built for any railways other than the inventor's own line.

4.—SUGGESTED TRIPLE-EXPANSION SCHEMES

In marine and stationary engine practice the triple-expansion engine, not to mention the quadruple, and even the quintuple, engine, is an acknowledged success; but in locomotive practice many engineers will deny that even the ordinary two-stage compound engine has really been satisfactorily produced, notwithstanding the good work done by present-day two, three and four-cylinder compound locomotives; and it is only the amateur inventors, whose productions lumber the patent records, who airily speak of triple, quadruple, quintuple, and even sextuple-expansion for locomotives.

Yet while these schemes, none of which have ever been tried in practice, are, as a whole, worthless, when an engineer of standing deals with the question, even although only on paper, it may be worth while to consider the suggestions, and, therefore, it is not out of place here to describe two triple-expansion locomotive designs suggested, respectively, by M. Mallet and by Mr. John Riekie.

In 1886 M. Mallet, writing to the In-

stitution of Mechanical Engineers in reference to Mr. Sandiford's four-cylinder compound engine already mentioned, outlined a suggested triple-expansion express locomotive. There were to be four coupled driving wheels, 7 feet in diameter, in the usual positions, and a single pair of 7-foot wheels in a bogie frame in front with the leading four wheels. The four coupled wheels were to be driven by an 18-inch high-pressure cylinder and a 26-inch intermediate cylinder, and the single driving wheels were to be driven by two 26-inch low-pressure cylinders. The arrangement is shown in Fig. 70.

Mr. Riekie's triple-expansion scheme Fig. 71, consisted in using two outside cylinders, one high-pressure and one intermediate pressure, and a large inside single-acting, low-pressure cylinder, all three cylinders driving on to one axle. The practical arrangement of this design depended upon the special features of the Riekie system, as described in Part II. of this article. The cylinders were to be 14, 20 and 28 inches in diameter, with a stroke of 26 inches. This design also included a triple boiler and various other departures from usual practice.

The engine has been referred to and illustrated in some locomotive books, generally to be depended on, as an actual engine for the North-Western Railway of Belouchistan (India), but this is not so. It is purely a design.

POSSIBILITIES OF DESIGN IN CARGO STEAMERS

By George Nicol, M. Inst. N. A.

IN designing a new vessel it is of the highest importance to have the special service for which she may be intended kept well in view. An expert designer will then be able to make her dimensions, form, and general arrangements in all respects suitable to the requirements, and it is very probable that the vessel when built will give satisfaction.

As it happens, however, it is only in the case of a comparatively small number of vessels that every detail of the proposed service is known. The great majority of vessels are engaged in general trading, these being commonly known as "tramps." The most that can be done for these vessels is to give them an all-round excellence, at least in respect to the points that experience has made clear.

It is easy to understand why the requirements of this class of vessel are so hard to define. The "tramp" steamer has to proceed to any port at which a freight may be obtained. This may be coal or iron, cotton or grain; in fact, anything that may offer itself, the main thing being to get a cargo, one in which there is a reasonable chance of a profit. While for any one kind of cargo a special vessel could probably be built to carry it better than any other, it is evident that in the general trader, which has to carry all kinds of cargoes, only a compromise can be made in order to meet the various requirements.

Still, with all these limitations, many splendid specimens of the modern cargo steamer are on the ocean, doing the carrying trade of the world, vessels which exhibit in design and execution all that is best in the shipbuilder's art.

From the hands of the constructors of such vessels an owner is certain to get a good ship, although he may be expected to pay somewhat for this satisfaction. Unfortunately, not many shipowners now entertain the same sentiment towards their sea-craft that was common in the old days. The modern owner of a "tramp" steamer is inclined to look upon his vessel as a profit-earning beast of burden, so to speak, which can never carry too much nor at too small a working cost. The consequence is that a shipowner who has capital to invest in new tonnage does not give his order at once to a reputable builder, but usually goes into the open market and buys from him who can offer the cheapest deadweight carrier.

While this is, of course, laudable, and shows keen business instincts, it is not fully appreciated that, in the matter of a ship, the cheapest vessel an owner may be able to have built may not always be the best investment for his money.

The truth of this statement the writer will now endeavour to prove by a practical illustration. Generally speaking, an owner in quest of a new vessel invites tenders from builders for one to carry a certain deadweight, the length and draught being sometimes given as additional conditions, and, it may be, an outline specification. With this information before him the builder sets to work to design the cheapest possible vessel which will do the work and fulfill the given conditions.

As is well known, vessels nowadays are constructed to conform to the rules of a classification society, this being necessary for insurance. This limits the shipbuilder considerably. He must obtain the hall-mark of the classification society, and his construction plans must be approved by that body; but still he endeavours to so design the vessel as to

make her construction as profitable as possible to himself.

This is, of course, allowable enough, if everything is done to make a seaworthy and sea-kindly vessel; but sometimes considerations of cost have been

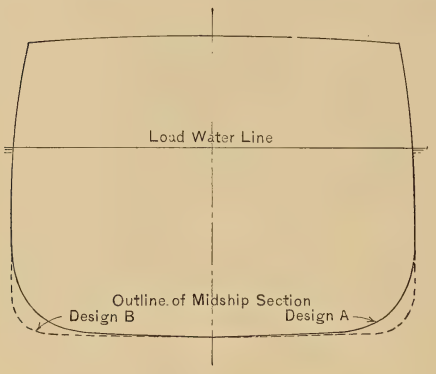


FIG. 1

allowed to outweigh all others, and this has not been done. The writer knows of such cases, and he feels sure that his knowledge in this connection is not without corroboration amongst those who have intimately to do with the cost, design, and construction of modern cargo steamers.

It is easy, by taking concrete examples, to show in what way the design of a vessel may be "skinned" down to cheapen construction, and also to show in what respects the vessel comes short in consequence.

Suppose, for example, that a builder is asked to quote a price for a vesael to carry 6000 tons deadweight, the length to be about 340 feet. It will be fouud that with this length a breadth of 48 feet and a depth of 27 feet 4 inches will be required. It is assumed that the vessel is to come under Lloyds, three-deck rule, and that she is to be built with a short, full poop, a bridge erection long enough to cover in the machinery and allow room for officers' accommodation in deckhouses on top, and a top-gallant forecastle. In the case of such a vessel actually built, the freeboard assigned permitted a draught of 22 feet 8¾ inches to bottom of keel, which was of the flat plate type. An estimate of weights can now be made. Basing the weight of hull on a somewhat similar vessel already built and whose particulars are tabulated in convenient form for easy reference, it will be found that the conditions for the new vessel are as follows:—

	Tons.
Weight of hull	2,090
Weight of machinery	335 (for 9 knots speed).
Ship's light weight	2,425
Deadweight	6,000
Total displacement	8,425

With this displacement at the above draught, namely, 22 feet 8¾ inches, the block coefficient of the vessel will be 0.795 on her extreme dimensions. Now, if this full vessel is to have a presentable form at all, it will of necessity have a full midship section, as shown by the dotted lines in Fig. 1. It will be observed that the rise of floor is 6 inches, and that the bilge is just rounded off to obviate a too boxy appearance. With such a midship section, the lines forward and aft may be made shapely,—to some extent, at least,—and quite in keeping with the speed required, nine knots. It will also be found that the metacentric

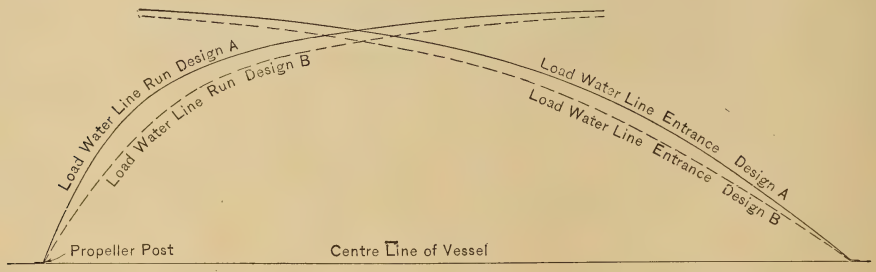
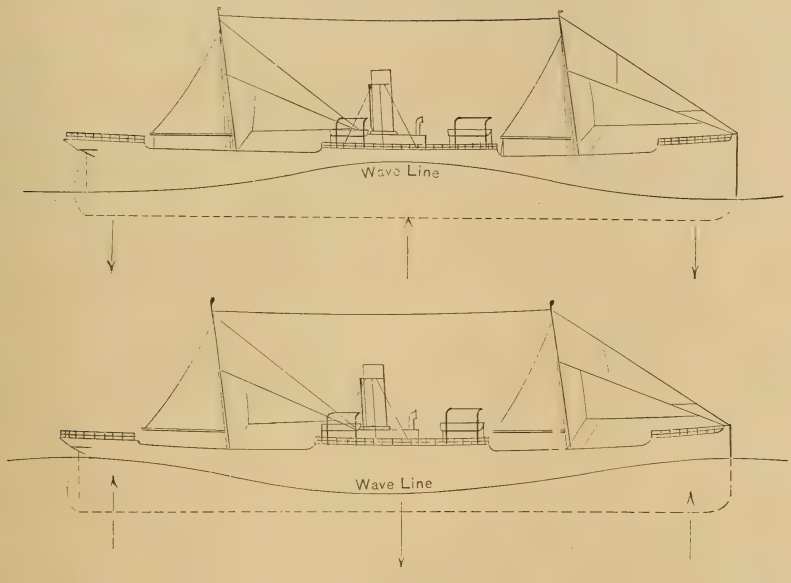

Load Water Line Run Design A
Load Water Line Run Design B
Load Water Line Entrance Design A
Load Water Line Entrance Design B
Propeller Post
Centre Line of Vessel

FIG. 2

height in the initial position will be sufficient, and that the curve of stability, when the vessel is loaded with a homogeneous cargo, will have considerable range. Altogether, if designed along these lines, the result will be quite a respectable cargo vessel.

The quick-witted builder, however, considers well the dimensions and the other conditions given, and endeavours to fulfill them all in the manner which offers most advantage to himself. Accordingly, he sets about reducing the classification numerals, and so gets the scantlings and equipment of the vessel seagoing and other qualities, such as speed, strength, stability and capacity, we shall, for easy reference, call the vessel with the fine midship section *A*, and the other *B*.

Speed.—It is clear that the extremely full ends which are now necessary in the case of the vessel *A* will make the angles of entrance and run very much steeper than with the vessel *B*, and will consequently lessen the speed at which resistance becomes abnormal. Fig. 2 shows the forward and after ends of the load water-line of each vessel, that of *A* being indicated in full lines, while the



FIGS. 3 AND 4

under a lighter grade than at first seemed possible. This he attains by fining the midship section until it assumes the form indicated in Fig. 1 in full lines. The saving in weight which results for this vessel will amount to about three per cent. of her total steel, and the builder is thus able to quote a somewhat lower price than his less expert rivals and still retain a good profit margin. He secures the contract; but, as we shall see presently, the owner does not get the vessel he would have got in the first instance.

In considering shortly how this alteration in form will affect her principal line for *B* is shown dotted. It is scarcely necessary to point out that the cost of working the full-ended vessel will be greater than that of the other. The same engines will not drive her so fast. The time consumed during a voyage will, therefore, be longer. This will mean a bigger coal bill and increased cost of wages for crew. Also, as it will take a longer time to earn the same amount of money, the return on the invested capital will be measurably reduced. This of itself is serious enough to demand attention.

Strength.—In calculations dealing

with the longitudinal strength of a vessel it is usual to imagine her first poised on a wave with the crest amidships, as shown in Fig. 3; and second, on two waves, with a crest at each end and a hollow amidships, as shown in Fig. 4. In each case the vessel is supposed to be in sea trim with full load. Separate calculations are necessary for each condition. When on the wave crest it will be found that there is an excess force of buoyancy acting on her amidships; while at each end, where the water has left the vessel, the weights will be in excess. The directions of these forces are indicated in the diagrams. It will thus appear that the vessel is in much the same position as a beam loaded generally at each end and supported in the middle. The tendency of these forces will

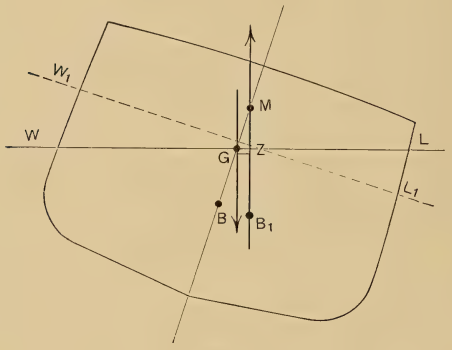


FIG. 5

be to give the vessel's form a curve upward amidships. In the second case the conditions are reversed, the hollow amidships causing the weights to be in excess there, while the wave crests at each end will ensure the predominance of a lifting force, the result being a tendency to alter the form, the middle dropping relatively to the ends.

It is only necessary to write down the ordinary stress formula to see in what way altering the form from B to A affects the strength of the vessel. Let

M=the bending moment acting on the vessel.
I=moment of inertia of midship section scantling.
p=stress on the material at a distance y from neutral axis.
y=greatest distance of material from neutral axis:

Then, $\frac{M}{I}=\frac{p}{y}$ or $p=\frac{My}{I}$

It is clear that p will be increased by reducing I and increasing M. Now, in vessel A the reduced midship section has necessarily reduced I, while the fuller ends with their greater load have increased M. We, therefore, see that the alteration in design has been in the direction of increasing the stress on the upper and lower parts, and as the material resisting the stress is rather less in scantling in A than in B, the former design is clearly the weaker.

Another very important point should be noted. Recent experience with full-ended vessels has shown that, when in a rough sea, severe local strains have been developed, resulting in loose rivets and consequent leakage.

These strains are undoubtedly due to the thrashing which the material at the ends of the vessel has to resist. The fuller the vessel is, the greater the exposed surface will be, and the more severe the thrashing strains. It appears, then, that in this particular also vessel A is deficient; and it is likely, from this cause alone, that the bill for repairs will be kept pretty constantly in evidence.

Stability.—On this question a comparison is not so easily made, and actual calculations should be gone into; but the general effect of the alteration in design may easily be demonstrated. Fig. 5 shows in cross-section a vessel afloat and heeled under the influence of certain forces; G is the centre of gravity of the floating vessel; B is the position of the centre of buoyancy when she floats upright at the water-line W_1 L_1; B_1 is the same centre when she is heeled over to the water-line W_1 L_1.

It is clear that when in the inclined position the resultant buoyant force due to the water displaced will act upwards through its centre B B_1. The weight of the vessel will act downwards through G, and it is seen, by referring to Fig. 5, that there is a righting moment tending to return the vessel to the original upright position. The lever G Z is a measure of the righting moment. The point M in which the vertical, through B_1, intersects the middle line, when the angle of heel is very small, is called the metacentre. In that case the distance

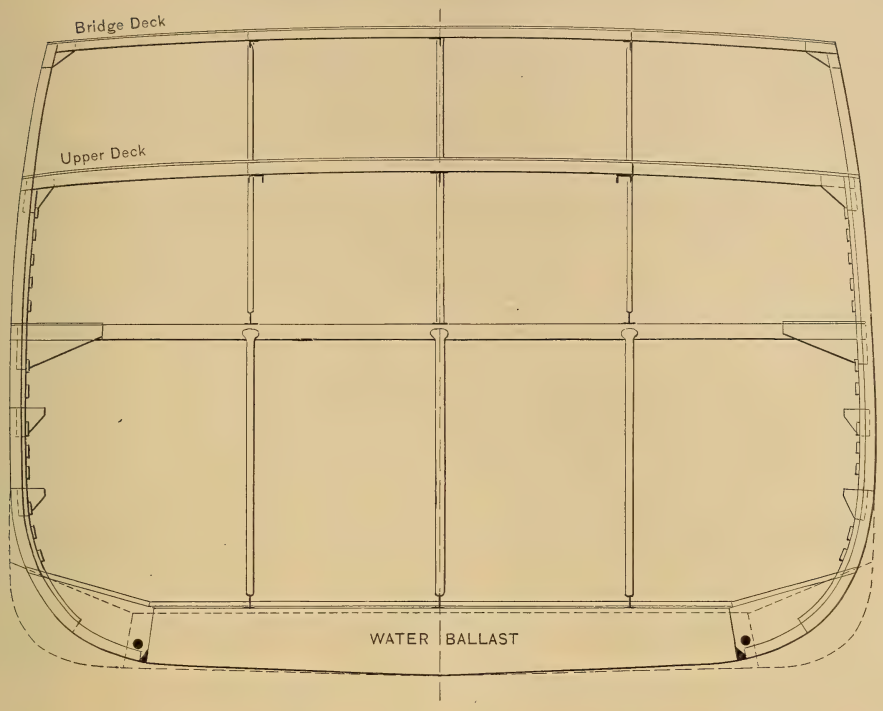


FIG. 6

$G\,M$ is known as the metacentric height, and, as a means of comparing the stability of vessels of somewhat similar form, it is important.

The centre of gravity G is fixed by the distribution of the weights, but M is influenced only by the under-water form of the hull. The height of M above the centre of buoyancy in the upright position,—

$$B\,M = \frac{\text{moment of inertia of water plane about its longitudinal axis.}}{\text{volume of displacement in cubic feet.}}$$

Now to turn to the vessels whose qualities we are comparing, it will be seen that the fine bilge in the design A will cause the centre of buoyancy to be somewhat higher in position than in the other, although the effect of the fine bilge will be somewhat neutralised by the extremely full ends, which will tend to bring the point down. Actual calculations show the point to be 2 inches higher in A than in B. Again, referring to the equation for $B\,M$, it would appear that the value of $B\,M$ in the full-ended vessel should exceed that in the other, as the water-line area is greater, and, therefore, its moment of inertia also is greater, while the volume of displacement remains constant in each case. Remembering, then, that the centre of buoyancy is slightly higher in design A than in design B, the absolute position of M above the keel will clearly be at a greater height in design A. Investigation shows it to be 7 inches higher.

It is, however, the distance between G and M that is of vital importance, and as G is considerably raised by the lifting of the bilge and the consequent raising of the machinery, water ballast, and other weights, it will probably be found that any difference in the metacentric height will be in favour of the more normally shaped vessel, which, as regards initial stability, if not a better boat, is certainly no worse.

Hold Capacity and Tonnage.—Owing to the raising of the bilge, it is not practicable to make the cellular ballast tank, which forms the inner skin, as wide in design A as in B. The consequent reduction in the ballast capacity is made

up by making the ballast tank somewhat deeper. Fig. 6 shows the midship section for both designs, *A* being shown by full and *B* by dotted lines. The figure shows in what manner the hold capacity is affected by resorting to design *A*. It is clear that a considerable reduction will result, and this will handicap the vessel when carrying light, bulky cargoes.

It ought to be pointed out, however, that the tonnage measurement will also be reduced, and this may be looked upon as compensating, to some extent, for the reduction in cargo space, as the tonnage dues, of course, are a standing charge on the vessel, reducing her earning power.

Summing up, then, the vessel proposed by the builder and stated to fulfill the conditions required as to deadweight and draught is found, on inquiry, to be deficient as to speed, strength, hold capacity, and probably stability, as compared with another vessel specially designed to attain all possible excellence in these particulars, with the same conditions. The writer states the foregoing only as one way in which the first cost of a vessel may be reduced; with other conditions, other ways would doubtless present themselves. But he is of the opinion that what he has pointed out is worthy of attention on the part of shipowners, and those who act for them; and he is convinced that care bestowed on the design even of a "cargo tramp" will be found amply repaid afterwards when she has taken her place among the world's freight carriers.

THE AMERICAN NEGRO ARTISAN

By Thomas J. Calloway

NEGRO TOBACCO STRIPPERS

WHETHER the artisans who built the pyramids of Egypt were negroes or of Caucasian identity may not be well settled. Recent history is quite clear, however, that American negroes, during slavery, developed marked mechanical skill and in many cases special inventive genius. Quite a large part of the mechanical work in the American Southern States before the Civil War was performed by slave artisans, these being valued much higher than ordinary farm hands and common labourers. This fact is so well known in the South that it has usually passed without comment; but Bruce, in his "Economic History of Virginia," makes the following reference to it:—

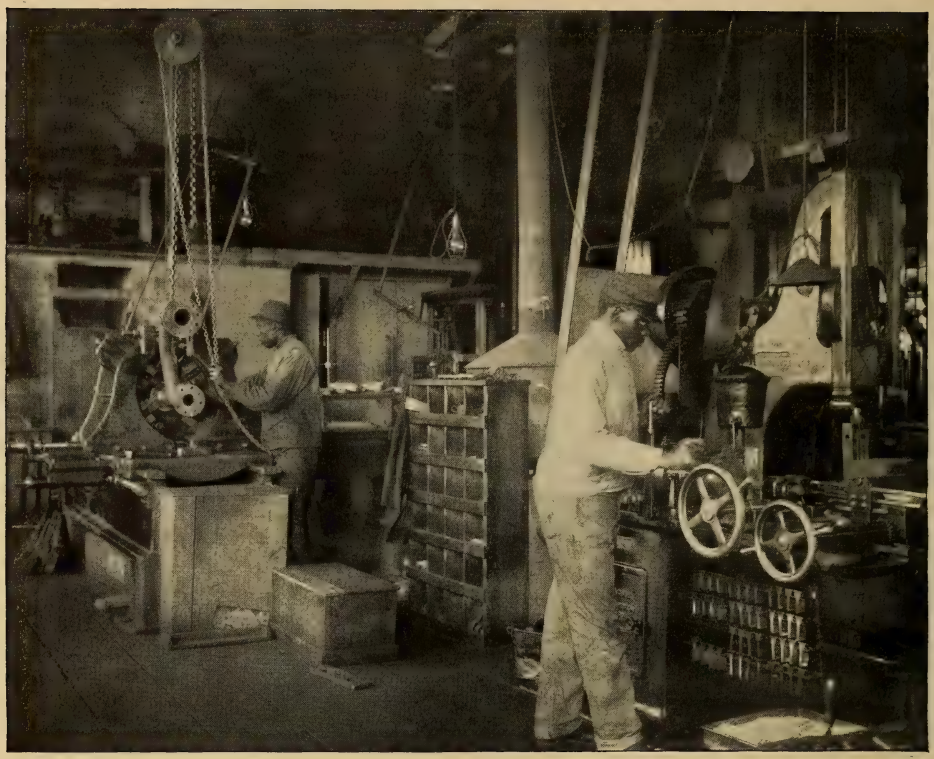
> The county records of the seventeenth century reveal the presence of many negro mechanics in the colony during that period, this being especially the case with carpenters and coopers This was what might be expected. The slave was inferior in skill, but the ordinary mechanical needs of the plantation did not demand the highest aptitude. The fact that the African was a servant for life was an advantage covering many deficiencies; nevertheless, it is significant that the large slaveholders like Colonel Byrd and Colonel Fitzhugh should have gone to the inconvenience and expense of importing English handicraftsmen who were skilled in the very trades in which it is certain that several of the negroes belonging to these planters had been specially trained. It shows the low estimate in which the planters held the knowledge of their slaves regarding the higher branches of mechanical work.

This historian might have added that the educational training that would have fitted the slaves for the higher grades of mechanical work would have unfitted them for their sphere of slavery. A somewhat different estimate of the negro mechanic is held by Ex-Governor Lowry, of Mississippi, who has said:—

> Prior to the Civil War there were a large number of negro mechanics in the Southern States; many of them were expert blacksmiths, wheelwrights, waggon-makers, brickmasons, carpenters, plasterers, painters, and shoemakers. They became masters of their respective trades by reason of sufficiently long service under the control and direction of expert white mechanics. During the existence of slavery the contract for qualifying the negro as a mechanic was made between the owner and the master workman.

The slavery system of training mechanics, which is sufficiently described in the two references, produced a type of negro artisan which served the plantation needs fairly well, and to some extent supplied town carpenters and village blacksmiths. With the passing of slavery, however, that type of artisan is also passing, and the question now arises as to what extent post-bellum negroes are finding their way into the trades. In the first place, it must be said that the slave descendants have not shown any special aptitude for the mechanic arts. This fact is all the more noteworthy because emancipation found the race in a practical monopoly in the South of all forms of labour, and it is to be regretted that some better form of leadership did not develop at that time so that the forty years past might have been more largely and beneficially utilised in holding the industrial foothold which the negro has been so steadily losing. It may in the future appear that the political effort following enfranchisement was not in vain, but from the view-point of the present it looks very much as if the negro had been repeating the experience of the children of Israel who spent their forty years wandering in the wilderness.

Under conspicuous leadership, of which Booker T. Washington is the chief exponent, the coloured people have had their attention directed to the



IN THE MACHINE SHOPS OF THE NEWPORT NEWS SHIPBULDING & DRY DOCK CO., NEWPORT NEWS, VA.

urgent necessity of clinging to the industrial occupations. Then, too, the tremendous industrial growth of all sections of the United States has drawn into its service all forms of labour. While race prejudice has kept the negro from some kinds of skilled labour, the greed for gold has forced him over the protest of prejudice into many of the trades.

There is an underlying trait of the African which enables the race to adjust itself to new conditions and environments, a trait that often leads him to become vicious when surrounded with vice just as easily as he becomes thrifty and progressive where the atmosphere in which he is thrown is that of thrift and progress. In fact, it is believed that no other race responds so quickly to external influences, be they climatic, moral, educational or industrial. The varied influences reaching out to the negro are already producing results that cause the future to look brighter for the race.

In the seventh bulletin of the Atlanta University Conferences, edited by Dr. W. E. B. DuBois, the events following emancipation are summed up very admirably. The editor says:—

> After emancipation, in the midst of war and social upheaval, the first real economic question was the self-protection of freed workingmen. There were three classes of them; the agricultural labourers, chiefly in the country districts; the house servants in town and country; and the artisans who were rapidly migrating to town. The Freedmen's Bureau undertook the temporary guardianship of the first class; the second class easily passed from half-free service to half-service freedom; the third class, the artisans, however, met peculiar conditions. They had always been used to working under the guardianship of a master, and even though that guardianship in some cases was but nominal, yet it was of the greatest value for protection. This soon became clear as the freed negro artisan set up business for himself. If there were a creditor to be sued, he could no longer bring suit in the name of an influential white master; if there were a contract to be had there was no responsible white patron to answer for the good performance of the work.
>
> Nevertheless, these differences were not strongly felt at first; the friendly patronage of the former master was often voluntarily given the freedman, and for some years following the war the negro mechanic still held undisputed sway.

Three occurrences, however, soon disturbed the situation;—the competition of white mechanics; the efforts of the negro for self-protection; and the new industrial development of the South.

* * * * *

What the negro mechanic needed, then, was social protection,—the protection of law and order, perfectly fair judicial processes, and that personal power which is in the hands of all modern labouring classes in civilised lands, viz., the right of suffrage. It has often been said that the freedman, throwing away his industrial opportunities after the war, gave his energies to politics and succeeded in alienating his friends and exasperating his enemies and proving his inability to rule. It is, doubtless, true that the freedman laid too much stress upon the efficacy of political power in making a straight road to real freedom. And, undoubtedly too a bad class of politicians, white and black, took advantage of this and made the reconstruction negro voter a hissing in the ears of the South.

Notwithstanding this the negro was fundamentally right. If the whole class of mechanics here, as in the Middle Ages, had been without the suffrage and half free, the negro would have had an equal chance with the white mechanic and could have afforded to wait. But he saw himself coming more and more into competition with men who had the right to vote; the prestige of race and blood; the advantage of intimate relations with those acquainted with the market and the demand.

The negro saw clearly that his rise depended, to an important degree, upon his political power and he, therefore, sought that power. In this seeking he failed primarily because of his own poor training, the uncompromising enmity and apprehensions of his white neighbours, and the selfishness and half-hearted measures of his emancipators. The result was that the black artisan entered the race heavily handicapped,—the member of a proscribed class, with restricted rights and privileges, without political and social power.

Any views of the negro artisan as such would be incomplete did they not include a consideration of the influence of his educational training since emancipation. With the dawn of freedom came the spelling book and the opportunity to acquire the three R's. A tremendous demand at once ensued for a corps of teachers, and salaries unusually large for coloured men and women up to that time soon drew the attention of the brightest minded from all other pursuits into the profession of instructing the youth of their race. The demand was so great that schools of higher training than the public schools were established all over the South for the proper equipment of teachers. The entire thought was given at first to the simple work of instilling the elements of literary learning, or, in other words, the higher schools aimed to instruct the students in the very studies they were called upon to teach later on in the public schools.

NEGRO WORKMEN ON ELECTRIC STREET RAILWAY WORK AT WASHINGTON, D. C.

As an additional impetus to the young people to educate themselves in this simple way there was an underlying conviction that all toil with the hands was a badge of slavery beyond which it was the duty of ambitious youth to aspire. It was an idea of slavery that physical labour was the duty of the bondman. Hence we find the emancipated parents, who were themselves

COLOURED COAL MINERS AT ELKHORN, WEST VIRGINIA

fairly well skilled in trades, making heroic struggles and sacrifices to the end that their children might have book learning, with a dim conviction that a knowledge of books was a royal pathway to all the desires of life. So long as the abnormal demand for teachers continued, the conviction was not without an apparent proof of its truthfulness.

A thorough student of race development would have seen clearly that any permanent growth must have included the training for some special form of activity in life. In fact, a departure from the universal preparation for teaching had already shown itself in the way of schools of medicine, law, and theology, in which aspirants to become doctors, lawyers, and preachers were prepared.

That the educational trend following emancipation was the result of the intoxication of sudden manumission is made clear from the vain attempts by free coloured people, as early as 1831, to establish trade schools where the free masses of their race might be equipped as artisans. Frederick Douglass, in 1853, led a formidable, but futile, effort to establish an industrial school. It was not, however, till the Hampton School, in Virginia, was established that industrial training for the negro may be said to have had its beginning. General Armstrong opened the school at the close of hostilities between the North and the South, and struggled with it for many years before the marked success of the institution was finally reached.

The principles of the institute were so thoroughly in harmony with common sense that it eventually won the hearty confidence and the material aid of philanthropists. In addition to the large number of its own graduates it has created a sentiment that has led to the establishment of many similar schools, one of which, the Tuskegee Institute, in Alabama, has surpassed the parent school in point of numbers.

About one hundred such schools offer industrial courses. Only a modest proportion of these, however, may be said be sufficiently equipped to do effective work in training students in any of the specialties set out. It would be difficult to select the most meritorious of these schools. A personal examination is pleasantly surprising in many instances in the case of schools of which little has been heard, and sadly disappointing in other cases where more was to have been expected. Without any attempt at an invidious comparison, it is believed that the large Hampton and Tuskegee schools are illustrating in their far-reaching spheres of influence what is being done in a lesser degree in many other places.

Industrial education, as the term has been generally employed in relation to negro schools of the South, has meant a system of education serving not only to give the elements of academic learning, but likewise to train, in shop and farm, young people who may fill the demands of the industrial world for skilled labour, be that labour agricultural, domestic, or manufacturing. Exponents and friends of the system have never claimed that the young people which it graduates can possibly be of that high degree of skill which results only from long application to a specialty; but the claim has been made, and, it is believed, proven by the results, that in an elemental and primary way the better-equipped industrial schools are fitting a superior grade of artisans for the trades.

Each of the industrial schools gives instruction in all or a portion of the following trades:—agriculture, horticulture, carpentry, blacksmithing, wheelwrighting, printing, painting, foundry and machine work, shoemaking, bricklaying, plastering, brick-making, sawmilling, tinning, harness-making, tailoring, plain sewing, dressmaking, millinery, cooking, laundering, nurse training, housekeeping, mechanical and architectural drawing, and perhaps others. The actual number of graduates from these schools who have entered into the trades is comparatively small, due to the greater demand for teachers and for persons to take other occupations for which a knowledge of the trades is a material aid. It has been estimated that the industrial schools have sent out

CHAPEL AT TUSKEGEE INSTITUTE, ALABAMA. BUILT BY NEGRO ARCHITECT AND STUDENT ARTISANS

about a thousand actual artisans, —not enough to man a single large manufacturing plant. As representing an awakening process, these thousand graduates must be regarded not so much for the actual proportion they represent to the millions of their race, but their true estimate is that of the compressed yeast cake which is leavening the infinitely larger race problems.

Having considered as fully as the plan here permits the formative influences of slavery, politics, and education upon the negro artisan, it is proper now to consider the actual status of the negro in the skilled industries. According to the United States Census of 1890, the distribution of bread-winning American negroes was in the following occupations:—

		Per cent.
Agriculture, fishing and mining	1,757,403	or 57
Domestic and personal service	963,080	31
Manufacturing and mechanical industries	172,970	6
Trade and transportation	145,717	5
Professional service	33,994	1

Taking the 6 per cent. of wage-earners found in manufacturing and mechanical industries, we find them, according to the same census, distributed as follows, omitting those occupations containing less than one thousand:—

Carpenters	22,318
Barbers	17,480
Saw-mill hands	17,230
Miners	15,809
Tobacco factory employees	15,004
Blacksmiths	10,762
Brick-makers	10,521
Masons	9,647
Engineers and firemen	7,662
Dressmakers	7,479
Iron and steel workers	5,790
Shoemakers	5,065
Mill and factory operatives	5,050
Painters	4,396
Plasterers	4,006
Quarrymen	3,198
Coopers	2,648
Butchers	2,510
Wood-workers	1,375
Tailors	1,280
Stone-crtters	1,279
Leather-curriers	1,099

The temptation is strong to pursue a further statistical view of the subject, but it is deemed more in harmony with the present discussion to make use of a

special investigation carried out in connection with the negro exhibit at the Paris Exposition of 1900. That exhibit was planned with a view to furnishing to Europeans a concise and carefully studied representation of life among American negroes.

It was felt by the writer of this article, who was the agent in charge of the preparation and superintendence of that exhibit, that no phase of the negro's life in America would so claim the attention of Europeans, as was afterwards proven, as his industrial status in the United States. Among other features, therefore, the effort was seriously made to present a narrative exhibit of the negro artisan. To this end an expert made a tour of inspection. The cities and towns visited were Atlanta and Augusta, in Georgia; Anniston, Hobson City, Pratt City, and Birmingham, in Alabama; Chattanooga and Knoxville, in Tennessee; Asheville, Charlotte, Concord, Greensboro, and Durham, in North Carolina; Columbia and Charleston, in South Carolina; and Richmond, in Virginia. Fifty-seven manufacturing plants were visited, employing 7244 coloured males and 1620 coloured females.

At Atlanta coloured men were found doing skilled labour in the manufacture of fertilisers and chemicals, the making of bricks, as coopers, waggon and buggy makers, shoemakers, and as size mixers and cotton classers in the cotton mills. They were generally employed in all branches of the building trades. At Anniston and Birmingham, Ala., and vicinity many thousands were employed in the mines and in the production of coke, pig-iron, and steel. Coloured

NEGRO BLACKSMITHS IN THE NEWPORT NEWS, VA., SHIPBUILDING YARDS

men were observed to be holding the responsible positions of foremen, cupola men, furnace keepers, and iron graders. At Knoxville, Chattanooga, Richmond, and indeed at all the places visited, negroes were employed as blacksmiths, blacksmiths' helpers, machinists' helpers, moulders, puddlers, rollers, roughers, catchers, furnace men, and boiler-

makers. At Knoxville, Tenn., hundreds of negroes were employed in cutting, shaping and polishing "Tennessee marble,"—a work requiring close attention and considerable skill. In the various places visited in North Carolina and Virginia coloured men were engaged in tanneries and tobacco factories; and throughout the South they are almost entirely used in the cotton-seed oil mills.

Interesting and valuable statistics were gathered during the tour of inspection, but it is believed that the following

we have employed negroes at these works in many occupations requiring skill and intelligence, with results eminently satisfactory. Two of the best blacksmiths we ever had were negroes. Another negro was for many years in charge of the air furnace in which we melted pig iron for heavy guns. In the rolling mills we have had, and still have, excellent rollers, charged with responsibility for trains of rolls and their product, heaters' helpers, roughers, catchers, and straighteners of this race. Negroes are also employed in punching fish bars and regulating our water wheels. In the foundry all our cupolas are manned by negroes. We may add that our relations with our negro workmen have always been pleasant.—Archer Anderson, President, The Tredegar Iron Co., Richmond, Va.

Our company have worked negroes in about all our departments since the year 1881. We found considerable trouble in teaching them to do pro-

A COTTON MILL AT CONCORD, NORTH CAROLINA, OWNED, BUILT, AND OPERATED BY NEGROES

signed letters from some of the factories visited will prove of special interest:—

As general manager of the Evans Marble Company I have been employing coloured men for the past twelve years and have found them steady, reliable and always to be depended upon. My experience with them as labourers has been that under proper treatment, they give the best satisfaction, are willing, contented, and rarely strike or join labour unions, and that with proper instruction they show great capability in marble finishing and the different processes thereof, such as bed rubbing, polishing, both manual and by machine, and in manipulating machinery for cutting and preparing marble to be polished, all of which requires close attention and considerable skill and experience.—J. E. Willard, Supt., Evans Marble Co., Knoxville, Tenn.

In answer to your letter of the 12th instant, we take pleasure in saying that for nearly fifty years

fessional work, and it cost us a very large amount of money to instruct them. We find, however, that since they have been properly taught they give equally as good service as the white labour.

We have had them employed as puddlers, heaters, rollers, roughers, and, in fact, have tried them in all departments of our works. We manufacture bar iron in its various forms, and, as stated before, we find that a coloured man gives equally good service and is really more adapted to the climate than the white labour of the North.—T. I. Stephenson, V. P. and G. M., Knoxville Iron Co., Tennessee.

The Richmond stemmery of the American Tobacco Company employs 1000 negroes for stemming tobacco, whose wages are $4.50 per week. For the class of work for which we employ them there is no other help in the world as good.—T. J. Walker, Richmond, Va.

We employ almost exclusively coloured labourers, who take up the work from the stage that

REFORMERS' HALL, DESIGNED BY A NEGRO ARCHITECT, AND ERECTED BY NEGRO CONTRACTORS AND MECHANICS

requires very little skill up to the finishing point where it does require some degree of skill and experience. Our experience with this labour has been very satisfactory indeed.—R. S. Bosher, Pres., T. C. Williams Tobacco Co., Richmond, Va.

Noteworthy examples are not wanting of individuals and enterprises that fully illustrate the upward strivings of the negro in mechanics. The Coleman Manufacturing Company is a capitalised corporation composed of coloured stockholders and is managed by a board of directors of the same race, of whom Warren C. Coleman, an ex-slave, is the president and general manager, as well as the largest stockholder. The company has built, equipped and is conducting a cotton mill at Concord, N. C. As race pride and race improvement were the moving spirits in the enterprise, a special effort was made to employ negro mechanics in all features of the construction and operation. The architect, the

A BROOM FACTORY WITH COLOURED EMPLOYEES, AT RICHMOND, VIRGINIA

A GROUP OF ALABAMA NEGRO MACHINISTS

brick-makers and masons, the carpenters and the factory employees now engaged in turning out a fair grade of cotton goods, sheetings, etc., are all coloured.

"Reformers' Hall," a business building, containing a theatre, office rooms, an armory, etc., has just been completed in the heart of Washington, D. C., at a cost of a hundred thousand dollars, by an architect, J. A. Lankford, contractors, and mechanics, all of the negro race. The building is finely appointed and thoroughly modern.

R. R. Taylor, instructor in mechanical and architectural drawing at the Tuskegee Institute, in Alabama, and the architect of the numerous buildings of that institution, is probably the best equipped in training and experience of any negro architect in the United States. He graduated from the Massachusetts Institute of Technology several years ago, and has designed a score or more of the buildings for the Tuskegee school, ranging in value from $50,000 downward. A chapel seating 2000 persons and a Carnegie library are his best designs.

The United States Patent Office was able to identify in 1900, through correspondence with patent attorneys, 357 patents issued to negroes. Probably as many more existed which could not be identified, inasmuch as the colour or race of the patentee does not enter into the application. This appears the more probable for the reason that 126 of the patents, or more than a third of the total number discovered, were issued in the five years immediately preceding the year 1900. The inventions are of a great variety of subjects, and while the number is not large, they are sufficient to show that the negro artisan, in common with other American mechanics, is contributing a portion to the remarkable growth of the United States.

Allowing for the recent emancipation of his body and the dense thralldom of ignorance in which chattel slavery left him, from which he is even now but half free, it is believed that the thoughtful "captains of industry" will see in the negro artisan a mine of valuable and reliable labour that is well worth their efforts to exploit.

THE WORLD'S NAVAL STRENGTH

By Alfred Smith

Although Mr. Smith's article was written entirely with reference to Great Britain's position among the naval powers, it will appeal with equal interest to readers of other nationalities, particularly at this time, and in view of the fact also that Mr. Smith's connection with Palmer's Shipbuilding & Iron Company, of Jarrow-on-Tyne, builders of war ships, and claimed to be the most extensive shipbuilding company in the world, carries with it assurance of accuracy in facts and figures. Whatever modification is to be made in these,—and some changes must be made now,—is due to the conflict between Japan and Russia, which has altered the number of ships on the lists when this article was written.—The Editor.

IT may not be inopportune, with the present unstable equilibrium of the world's peace, to review briefly our naval strength in relation to other powers, and if any apology be needed for referring again to a subject which engages a large share of public attention, we must plead the all-sufficient reason that our empire is found on the sea more to-day than ever before, and the full preservation of our rights and interests there is a matter of paramount importance to every Briton. We cannot, therefore, keep it too clearly in view or debate it too often.

In attempting a comparison between Great Britain's naval power and that of other nations there is much to be borne in mind besides numerical strength. Of course, in any comparison the number of ships is the chief consideration,—their fighting power and fitness or otherwise to operate against the enemy, their age, size, armament, speed and general equipment for service. Other questions, however, enter into the range of discussion. There is the personnel of the fleet, the organisation and intelligence of the service, and the power of adaptability to circumstances,—to get the most out of whatever ships they may happen to possess. Past history teaches us that the victory has not always been with the greatest number of ships, but has been determined largely by the personal element, the genius of the captain, and the worth of his crew. We live, however, in a different age, and history is no longer a safe guide, although the human element will still count for something in the day of battle.

Then there are the work the fleet has to do, the geographical position of the nations concerned, the seaboard to be protected, and the extent to which a country is dependent for its life upon its control of the sea. The last-named point appeals particularly to Great Britain in view of her insular position, her great population, and her almost entire dependence upon foreign grain for very life. Napoleon used to say that armies moved upon their bellies. Everybody does so, and a starving civilian population would end a war quicker even than armed legions or fighting ships. Starvation has ever been a strong weapon of warfare, and it is well for Great Britain, therefore, to bear in mind that in wheat she grows only a fifth of what her people eat.

Moreover, it is not only food which must reach Great Britain's shores. Raw material must enter her ports, first, to provide work for her people so that they may have the wherewithal to purchase bread; and, second, to keep her works going, say, in manufacturing steel in its varied forms for the building or repair of ships and engines to carry on the struggle. If Great Britain's supplies of iron ore, for example, were stopped for a month

her steel industry would be at a standstill.

Another consideration is the possession of colonies,—their extent and liability to attack; their loyalty, and the power they would, or could, exert to defend themselves against the enemy of the mother country. In this respect Great Britain has greater responsibilities than other nations, first, because she owns the greatest colonies; and, second, because they are either surrounded by water or their seaboard is extensive. Then there might be noted the naval stations possessed by the various countries,—geographical positions strongly held, which tend to strengthen the nation possessing them while weakening the attacking force. Gibraltar may be taken as a case in point,—a position which should be worth a good many ships to Great Britain, just as the Kaiser Wilhelm Canal is of great value to Germany, enabling that nation to assemble its fleet in either the North or Baltic seas without going round by Denmark, thus avoiding the risk of an attack in the Skager Rack and Cattegat.

It is impossible here to go thoroughly into the points we have raised. But let us glance first at the numerical strength of the principal navies. Taking each class of vessel we may, by analysis, arrive approximately at the relative positions of the chief naval powers, which are Great Britain, France, Russia, Germany, Italy, the United States, and Japan. These nations have between them altogether 1963 war vessels of all classes, disposed as in Table I. This includes all vessels, whether launched or building.

If we deduct 856 torpedo boats and 63 submarine boats, we have left 1044 ships. Of the grand total, Great Britain's proportion is 24.6 per cent., or 483 ships, and if we exclude torpedo boats and submarine vessels, her strength is 384 ships, or 36.5 per cent. Thus Great Britain has in the more important classes of war vessels over one-third of the whole. To appreciate the real value, however, of this share, it is necessary to analyse it and see wherein Britain is strongest, whether in battleships, or cruisers, or less powerful craft. Table II. shows the proportion of the total of each class of vessel owned by each of the nations named.

Scouts do not appear in the above list, as Great Britain alone possesses this class,—four now built and four building, and they lie between an unprotected cruiser and a torpedo vessel. The table is satisfactory as far as it goes. Great Britain's percentage in first-class battleships is double that of any other two powers, while in armoured cruisers her lead is even more pronounced. But to enable one to appraise their real worth the inquiry must be carried further,—the age of the vessels ascertained. Dealing with the total of 1044 vessels, they have been divided, first, into those launched before 1885, and then into the three periods of six years from 1885 to 1902, leaving 1903 to stand alone, with the result given in Table III.

This table is interesting as showing the age of the world's fleets as a whole. To be useful as a means of determining the superiority of one nation over another it is necessary to dissect it further to see which country has the largest number of modern boats in each class. This necessitates Tables IV. to VIII.

It will be observed that of the total number of vessels down to destroyers 10½ per cent. were launched before 1885, 17.3 per cent. between 1885-90, 25.9 per cent. between 1891-96, 34.6 per cent. between 1897-02, while 1903 claims 11.7 per cent. Nearly half of the total vessels have, therefore, been put into the water during the last six years or are now building. If we omit vessels launched before 1885 as old and inefficient, and ignore those under 1903, we have 812 vessels. On this basis, Great Britain has 325 ships, the other nations' share being 487. As between Great Britain on the one hand, and France, Russia and Germany on the other, on this basis the position stands as shown in Table IX.

Taking a broad view, Great Britain has nothing to fear from any one power. What she has to provide against is a combination, and it is never a safe policy to count upon impossible alliances.

TABLE I

	Great Britain	France	Russia	Germany	Italy	United States	Japan	Total
First class battleships	54	26	21	20	18	19	6	164
Second class battleships	4	9	4	4	--	1	1	23
Third class battleships	2	1	1	12	5	--	--	21
Coast defence vessels	2	14	13	11	--	16	2	58
Armoured cruisers	37	22	8	5	6	13	6	97
First class protected cruisers	21	7	9	1	--	3	--	41
Second class protected cruisers	53	16	7	8	5	17	12	118
Third class protected cruisers	36	17	--	15	11	2	9	90
Unprotected cruisers	10	1	3	20	--	11	9	54
Torpedo vessels	34	16	9	2	14	--	1	76
Torpedo boat destroyers	131	33	54	32	13	20	19	302
Torpedo boats	90	265	139	93	153	31	85	856
Submarines	9	40	2	--	4	8	--	63
Totals	483	467	270	223	229	141	150	1,963

TABLE II

	No. of Ships	Great Britain Per Cent	France Per Cent	Russia Per Cent	Germany Per Cent	Italy Per Cent	United States Per Cent	Japan Per Cent
First class battleships	164	32.9	15.8	12.8	12 2	10.9	11.5	3.6
Second class battleships	23	17.3	39.1	17.3	17.3	---	4.3	4.3
Third class battleships	21	9.5	4.8	4.8	57.1	23.8	---	---
Coast defence vessels	58	3.5	24.1	22.4	18.9	---	27.5	3.5
Armoured cruisers	97	38.1	22.6	8.2	5.1	6.1	13.4	6.2
First class protected cruisers	41	51.2	17.0	21.9	2.4	...	7.3	---
Second class protected cruisers	118	44.9	13.5	5.9	6.7	4.2	14.4	10.1
Third class protected cruisers	90	40.0	18.8	---	16.6	12.2	2.2	10.0
Unprotected cruisers	54	18.5	1.8	5.5	37.0	---	20.3	16.6
Torpedo vessels	76	44.7	21.0	11.8	2.6	18.4	---	1.3
Torpedo boat destroyers	302	43.3	10.9	17 8	10.6	4.3	6.3	6.2
Torpedo boats	856	10.5	30.9	16.2	10.8	17.8	3.6	10.0
Submarine vessels	63	14.2	63.5	3.2	---	6.3	12.6	---
Total	1,963							

TABLE III—NUMBER OF VESSELS LAUNCHED AND BUILDING

	Previous to 1885	1885 to 1890	1891 to 1896	1897 to 1902	1903	Total
First class battleships	11	19	49	58	27	164
Second class battleships	11	5	6	1	--	23
Third class battleships	12	3	6	--	--	21
Coast defence vessels	37	8	9	4	--	58
Armoured cruisers	5	10	11	42	29	97
First class protected cruisers	--	5	17	16	3	41
Second class protected cruisers	7	32	51	19	9	118
Third class protected cruisers	5	37	14	26	8	90
Unprotected cruisers	22	24	7	1	--	54
Torpedo vessels	--	38	36	2	--	76
Torpedo boat destroyers	--	--	64	192	46	302
Totals	110	181	270	361	122	1,044

TABLE IV—VESSELS LAUNCHED PREVIOUS TO 1885

	Great Britain	France	Russia	Germany	Italy	United States	Japan	Total
First class battleships	2	4	--	--	5	--	--	11
Second class battleships	4	2	--	4	--	--	1	11
Third class battleships	1	1	1	4	5	--	--	12
Coast defence vessels	2	7	6	11	--	10	1	37
Armoured cruisers	2	1	2	--	--	--	--	5
First class protected cruisers	--	--	--	--	--	--	--	--
Second class protected cruisers	3	1	--	--	1	2	--	7
Third class protected cruisers	1	--	--	--	--	--	4	5
Unprotected cruisers	2	1	3	9	--	4	3	22
Torpedo vessels	--	--	--	--	--	--	--	--
Torpedo boat destroyers								
Totals	17	17	12	28	11	16	9	110

One cannot be sure, for example, that France will never join Germany, or that Russia, Germany, and France may not, under given conditions, find an alliance against Great Britain of common benefit to them. Omitting any one of the above nations, Great Britain's strength in vessels launched since 1885 and not counting 1903, is well maintained up to the two-power standard, but no further, for,

TABLE V—1885–1890

	Great Britain	France	Russia	Germany	Italy	United States	Japan	Total
First class battleships	7	5	3	--	4	--	--	19
Second class battleships	--	2	3	--	--	--	--	5
Third class battleships	1	--	--	2	--	--	--	3
Coast defence vessels	--	6	1	--	--	--	1	8
Armoured cruisers	7	1	2	--	--	--	--	10
First class protected cruisers	3	2	--	--	--	--	--	5
Second class protected cruisers	12	3	2	2	4	5	4	32
Third class protected cruisers	20	10	--	1	3	2	1	37
Unprotected cruisers	8	--	--	7	--	4	5	24
Torpedo vessels	18	8	3	1	8	--	--	38
Torpedo boat destroyers	--	--	--	--	--	--	--	--
Totals	76	37	14	13	19	11	11	181

TABLE VI—1891–1896

	Great Britain	France	Russia	Germany	Italy	United States	Japan	Total
First class battleships	20	10	7	5	1	4	2	49
Second class battleships	--	4	1	--	--	1	--	6
Third class battleships	--	--	--	6	--	--	--	6
Coast defence vessels	--	1	6	--	--	2	--	9
Armoured cruisers	--	4	2	--	3	2	--	11
First class protected cruisers	11	2	--	1	--	3	--	17
Second class protected cruisers	32	11	1	1	--	3	3	51
Third class protected cruisers	3	4	--	1	5	--	1	14
Unprotected cruisers	--	--	--	4		3	--	7
Torpedo vessels	16	6	6	1	6	--	1	36
Torpedo boat destroyers	63	--	1	--	--	--	--	64
Totals	145	42	24	19	15	18	7	270

TABLE VII—1897–1902

	Great Britain	France	Russia	Germany	Italy	United States	Japan	Total
First class battleships	20	2	10	10	4	8	4	58
Second class battleships	--	1	--	--	--	--	--	1
Third class battleships	--	--	--	--	--	--	--	--
Coast defence vessels	--	--	--	--	--	4	--	4
Armoured cruisers	15	12	2	4	3	--	6	42
First class protected cruisers	7	3	6	--	--	--	--	16
Second class protected cruisers	4	1	2	5	--	4	3	19
Third class protected cruisers	8	3	--	10	3	--	2	26
Unprotected cruisers	--	--	--	--	--	--	1	1
Torpedo vessels	--	2	--	--	--	--	--	2
Torpedo boat destroyers	50	17	48	29	11	20	17	192
Totals	104	41	68	58	21	36	33	361

TABLE VIII—1903

	Great Britain	France	Russia	Germany	Italy	United States	Japan	Total
First class battleships	5	5	1	5	4	7	--	27
Second class battleships	--	--	--	--	--	--	--	--
Third class battleships	--	--	--	--	--	--	--	--
Coast defence vessels	--	--	--	--	--	--	--	--
Armoured cruisers	13	4	--	1	--	11	--	29
First class protected cruisers	--	--	3	--	--	--	--	3
Second class protected cruisers	2	--	2	--	--	3	2	9
Third class protected cruisers	4	--	--	3	--	--	1	8
Unprotected cruisers	--	--	--	--	--	--	--	--
Torpedo vessels	--	--	--	--	--	--	--	--
Torpedo boat destroyers	18	16	5	3	2	--		46
Totals	42	25	11	12	6	21	5	122

TABLE IX

	Great Britain	France	Russia	Germany	
First class battleships	47	17	20	15	=52
Second class battleships	--	7	4	--	=11
Third class battleships	1	--	--	8	= 8
Coast defence vessels	--	7	7	--	=14
Armoured cruisers	22	17	6	4	=27
First class protected cruisers	21	7	6	1	=14
Second class protected cruisers	48	15	5	8	=28
Third class protected cruisers	31	17	--	12	=29
Unprotected cruisers	8	--	--	11	=11
Torpedo vessels	34	16	9	2	=27
Torpedo boat destroyers	113	17	49	29	=95
		120	106	90	
Totals	325		316		316

TABLE X

	Previous to 1885 Per Cent	1885 to 1890 Per Cent	1891 to 1896 Per Cent	1897 to 1902 Per Cent	1903 Per Cent
Great Britain	15.4	42.0	54.0	28.6	34.4
France	15.4	20.4	15.5	11.1	20.5
Russia	10.9	7 7	9 0	18.9	9.0
Germany	25.4	7.1	7.0	16.0	9.9
Italy	10.0	10 5	5.5	6.0	4.9
United States	14.5	6.0	6.5	10 0	17.2
Japan	8 1	6,0	2.5	9.1	4.1

TABLE XI—GREAT BRITAIN'S PROPORTION OF WAR SHIPS LAUNCHED AND BUILDING

	Previous to 1885 Per Cent	1885 to 1890 Per Cent	1891 to 1896 Per Cent	1897 to 1902 Per Cent	1903 Per Cent
First class battleships	18.18	36.84	40 81	34.47	18.5
Second class battleships	36.3	----	----	----	----
Third class battleships	8 3	50.0	----	----	----
Coast defence vessels	5.4	----	----	----	----
Armoured cruisers	40.0	70.0	----	35.7	44.8
First class protected cruisers	----	60.0	64.7	43.7	----
Second class protected cruisers	42.8	37.5	62.7	21.0	22.2
Third class protected cruisers	25.0	54.0	21.4	30.7	50.0
Unprotected cruisers	9.9	33.3	----	----	----
Torpedo vessels	----	47.3	44.4	----	----
Torpedo boat destroyers	----	----	98.0	26.0	30.1

in respect of the heaviest boats, she falls back when contrasted with the three powers.

Taking the analysis of the whole,—excluding destroyers, torpedo boats and submarines,—a step further, we can see from Table X. how the different nations compare as regards age.

It will be noted that Great Britain's great lead in the period from 1885-96 drops in 1897-1902, due to the special efforts made by other nations, notably Germany and Russia. This, of course, deals with the total number of vessels. Great Britain's proportion of each class of vessels for the periods named is given in Table XI.

As regards battleships, Britain is not maintaining her lead. Twenty ships added between 1891-96 showed her proportion to be 40.81 per cent. The same number of ships added during the following six years showed the proportion to be only 34.47 per cent., while of the vessels under 1903 the proportion is only 18.5 per cent. Against this, however, may be noted the increasing share of the armoured cruisers,—vessels which combine good fighting power with high speed, and are, for all practical purposes, as good as battleships. As these two classes constitute the backbone of a navy, and will probably be the determining factors in the next war, it might be well to make a further investigation in order to ascertain how Great Britain stands as regards size. Generally, but not necessarily, numbers mean strength. A knowledge of the average displacement will, however, tell whether the British vessels are equal to those of the other powers.

We have seen that the British strength in battleships is 54 vessels. Their total displacement is 740,350 tons, or an average of 13,710 tons. France comes next with 26 ships; her total displacement being 311,421, which gives 11,977 tons average. Russia's 21 ships give her the third place, and they total up to 255,193 tons, or an average of 12,152 tons. The next nation in point of numbers is Germany, whose 20 vessels give her a total displacement of 230,563 tons, or an average of 11,528 tons, whereas the 19 vessels of the United States displace 243,777 tons, an average of 12,925 tons. In armoured cruisers, it appears that the 37 British vessels displace 374,800 tons, or an average of 10,135 tons per vessel. The number of battleships gives Great Britain 32.9 per cent. of the total of 164 vessels, but in displacement her percentage rises to 35.4 per cent., while in armoured cruisers her proportion of the total of 97 ships was 38.1 per cent. and of displacement 39.9 per cent., showing that the British vessels are generally heavier than those of the other powers. The United States'

TABLE XII

	FIRST CLASS BATTLESHIPS			ARMOURED CRUISERS		
	No. of Ships	Total Displacement Tons	Average Displacement Tons	No. of Ships	Total Displacement Tons	Average Displacement Tons
Great Britain	54	740,350	13,710	37	374,800	10,135
France	26	311,421	11,977	22	192,269	8,749
Russia	21	255,193	12,152	8	71,261	8,907
Germany	20	230,563	11,528	5	46,395	9,279
Italy	18	222,976	12,387	6	39,185	6,530
United States	19	243,777	12,925	13	157,595	12,122
Japan	6	84,300	14,050	6	58,150	9,691
Great Britain's perce't'ge=	32.9 p.c.	35.4 p.c		38.1 p.c.	39.9 p.c.	

TABLE XIII—VESSELS LAUNCHED PREVIOUS TO 1885

	FIRST CLASS BATTLESHIPS			ARMOURED CRUISERS		
	No. of Ships	Total Displacement Tons	Average Displacement Tons	No. of Ships	Total Displacement Tons	Average Displacement Tons
Great Britain	2	19,800	9,900	2	16,800	8,400
France	4	44,207	10,551	1	6,110	6,110
Russia	--	------	------	2	11,793	5,896
Germany	--	------	------	--	------	------
Italy	5	64,986	12,097	--	------	------
United States	--	------	------	--	------	------
Japan	--	------	------	--	------	------

TABLE XIV—1885 TO 1890

Great Britain	7	76,450	10,921	7	39,200	5,600
France	5	53,507	10,701	1	6,676	6,676
Russia	3	32,159	10,719	2	15,258	7,629
Germany	--	------	------	--	------	------
Italy	4	49,485	12,371	--	------	------
United States	--	------	------	--	------	------
Japan	--	------	------	--	------	------

TABLE XV—1891 TO 1896

Great Britain	20	280,650	14,032	--	------	------
France	10	116 046	11,604	4	18,853	4,713
Russia	7	79,138	11,305	2	24,125	12,062
Germany	5	50,470	10,094	--	------	------
Italy	1	13,087	13.087	3	17,303	5,767
United States	4	42,204	10,551	2	17,415	8,707
Japan	2	24,750	12,375	--	------	------

TABLE XVI—1897 TO 1902

Great Britain	20	281,700	14,085	15	177,400	11,826
France	2	26,491	13,245	12	115,980	9,665
Russia	10	130,380	13,038	2	20,085	10,042
Germany	10	115,108	11,510	4	37,047	9,261
Italy	4	45,718	11,429	3	21,882	7,294
United States	8	94,833	11,854	--	------	------
Japan	4	59,550	14,887	6	58,150	9,691

TABLE XVII

Great Britain	5	81,750	16,350	13	141,400	10,877
France	5	73,170	14,634	4	44,650	11,162
Russia	1	13,516	13,516	--	------	------
Germany	5	64,985	12,997	1	9,348	9,348
Italy	4	49,700	12,425	--	------	------
United States	7	106,740	15,249	11	140,180	12,743
Japan	--	------	------	--	------	------

TABLE XVIII—AVERAGE NUMBER OF THE HEAVIER GUNS PER SHIP ON FIRST-CLASS BATTLESHIPS AND ARMOURED CRUISERS LAUNCHED AND BUILDING

	Previous to 1885		1885–90		1891–96		1897–02		1903	
	B	C	B	C	B	C	B	C	B	C
Great Britain	10	14	11	12	14.9	--	15.8	15	18	13.4
France	16.8	11	17.8	8	17.7	8	21	15	22	16.5
Russia	--	13.5	13	16.5	14.1	23	16.2	15	16	--
Germany	--	--	--	--	14	--	21.6	14	18	14
Italy	13.2	--	19	--	28	17.3	20	17	14	--
United States	--	--	--	--	16.5	19	19.7	--	23.5	17.2
Japan	--	--	--	--	14	--	18	17.3	--	--

average displacement in armoured cruisers is, however, in excess of the British, —12,122 tons, which, on 13 vessels, gives a total of 157,599 tons. Putting the matter into tabular form, as in Table XII., we see the position of the various nations at a glance.

From this it is seen that as far as displacement goes, the British battleships are the most powerful, but that the United States cruisers are heavier than the British. Displacement, however, is not everything. What proportion of that displacement is modern? To answer this is to arrive at a better idea of its value, and it necessitates another set of tables. Proceeding upon the same basis as before as regards periods, we arrive at the results given in Tables XIII. to XVIII.

It will be noted that Great Britain is building the largest battleships, but that the British cruisers are smaller than the French ships. What Great Britain thus loses in displacement, however, she gains in number. The United States are well represented both as regards numbers and weight. The absence of any armoured cruisers for Britain for the period 1891-96 (Table XV.) is due to the fact that during that period she was cultivating protected cruisers which were subsequently abandoned. Generally, however, the tables establish British superiority as regards modern battleships and cruisers of heavy displacement.

The question of armament is, of course, an all-important one, as upon gun power,—efficiency as well as numbers,—the issue of a fight will largely depend. However, we will assume,—and the assumption is submitted as a fair one,—that, generally speaking, age first and foremost will determine the efficiency of any fighting machine. The newest ship will naturally embody the latest improvements for doing its work. This covers the question of guns. It may be of interest to note that dealing with the heavier guns (omitting such as 12-pounders and smaller arms) in battleships and armoured cruisers we get for the different countries the results given in Table XVIII.

From this it will be seen that the United States had the greatest number to their credit in 1903. Of British undisputed superiority in torpedo boat destroyers it is needless to speak. Their place in the fleet and their fighting worth really remain to be determined. Originally built to destroy torpedo boats, they are in the British Navy taking the place of the torpedo boat itself. They are popularly expected to do much in the way of destroying commerce, but it is open to doubt whether they would be as formidable in this direction as is generally expected.

Speaking of commerce calls to mind that Great Britain owns a mercantile marine larger than the rest of the world put together, which, however gratifying in times of peace, will throw an enormous responsibility upon the British Navy in time of war. Approximately, for every warship, Great Britain owns twenty merchant craft; the same proportion will apply to the United States, while Germany has ten, France three and Russia five. It will thus be seen how much more than Continental rivals the British fleet will have to do. The fact that Great Britain is surrounded entirely by water constitutes alike her safety and her peril. Other nations are not so situated. To get at Great Britain would be comparatively easy provided the enemy's fleet were powerful enough. A state of siege in the British Isles would mean defeat, implying that Great Britain had lost the power to attack. She must, therefore, have a fleet capable not only of defence, but offence; that is, to drive off the enemy and maintain her ocean communications,—retain not only command of her own shores, but positively of the sea itself,— the great ocean routes used by her mercantile marine.

The British fleet is none too large for this stupendous task. Nor, by the way, can Great Britain be quite sure that her mercantile marine is a training institution,—as it should be under well-ordered conditions,—for reserve seamen to fight her battles, since an ever-increasing number of foreigners are receiving an excellent training in it which might conceivably be turned against her. The

possession of this huge merchant fleet is assumed by some to constitute a valuable standby for Great Britain in that she could, in times of emergency, lay hands upon a large number of vessels for the purpose of fitting them out as warships. The general assumption may be right so far, always provided that it were possible to find guns to arm the vessels, and that their stability and other qualities would permit of their being so fitted. They might defeat a similar vessel, destroy commerce, or do some minor service; but in meeting with a warship pure and simple their wisest course would be to run away, and speed would count for everything under such conditions.

British power to build rapidly in order to replace losses, or the facilities at the disposal of Great Britain for repairs, may be noted in passing, although it may be doubted whether in a naval war the opportunities for taking advantage of these facilities would be worth much, since the victor in any considerable action would probably push the first decisive blow to its logical conclusion. That there may be no doubt as to the issue of a sea struggle when Great Britain may be called upon to engage in it should cause every Briton to see that the country's naval resources are equal to meet any possible call without anxiety,—to maintain her ocean supremacy and vast colonial possessions. Their loss would witness Great Britain's disappearance as a world power.

PAUL M. LINCOLN

A BIOGRAPHICAL SKETCH

THE young man's prominence in engineering, as in other lines of work, so frequently emphasised as typical of the times in the United States if not elsewhere, is well illustrated by the career of Mr. Paul M. Lincoln, of the engineering department of the Westinghouse Electric & Manufacturing Company, of Pittsburgh.

Mr. Lincoln was born at Norwood, Michigan, on January 1, 1870, and after graduating from the public schools attended Adelbert College, at Cleveland, Ohio, for one year,—from 1888 to 1889,—and the Ohio State University for the succeeding two years and a half, leaving at the end of the first term of the senior year to accept a position with the Short Electric Railway Company, of Cleveland, Ohio. By special arrangement, however, with the University faculty, he was allowed to take examinations in

the college work from time to time, and was thus eventually enabled to graduate with his class in the summer of 1892.

He continued work with the Short Company until December, 1892, at which time he was offered a position with the Westinghouse Company at Pittsburgh. This he accepted, remaining in their employ until February, 1895, when he accepted an offer from the Niagara Falls Power Company to look after their electrical installations, which began to supply current commercially a little later in that year. His work at Niagara Falls continued for the next seven years,—until May, 1902,—when he again returned to Pittsburgh to resume his connection with the Westinghouse Company. There his labours are closely merged with the achievements of the company as one large aggregation of engineering talent. One of the fruits of his work,—the best known, perhaps,—is the "Lincoln synchroniser,"—an instrument designed for the purpose of making easier the paralleling of alternating-current generators. This was awarded a bronze medal at the Buffalo Electrical Exhibition in 1901, and the John Scott medal of the Franklin Institute of Philadelphia, in 1902.

Mr. Lincoln is a member of the American Institute of Electrical Engineers, the American Electrochemical Society, the Franklin Institute, and the Engineers' Society of Western Pennsylvania. He is also a fellow of the American Association for the Advancement of Science, and has actively contributed to the transactions of most of these institutions.

THE ESCALATOR

By Charles D. Seeberger

AN ESCALATOR AT THE TWENTY-THIRD STREET STATION OF THE SIXTH AVENUE ELEVATED RAILROAD, NEW YORK

A DESCRIPTION of the escalator, or moving stairway, may be properly prefaced by a statement of the conditions it is to meet and the demand it is intended to supply.

The tendency to concentration of population is world-wide, but has reached its maximum in the United States, where the development of transportation facilities has kept pace with the rapid de-

ONE OF THE ESCALATORS IN THE DEPARTMENT STORE OF R. H. MACY & CO., NEW YORK. THIS IS ONE OF A SERIES OF SIX SIMILAR ONES LEADING FROM FLOOR TO FLOOR

velopment of the builder's art, by which tens of thousands now conduct affairs in the great buildings of twenty stories or more, occupying ground areas which, a few years ago, accommodated only hundreds.

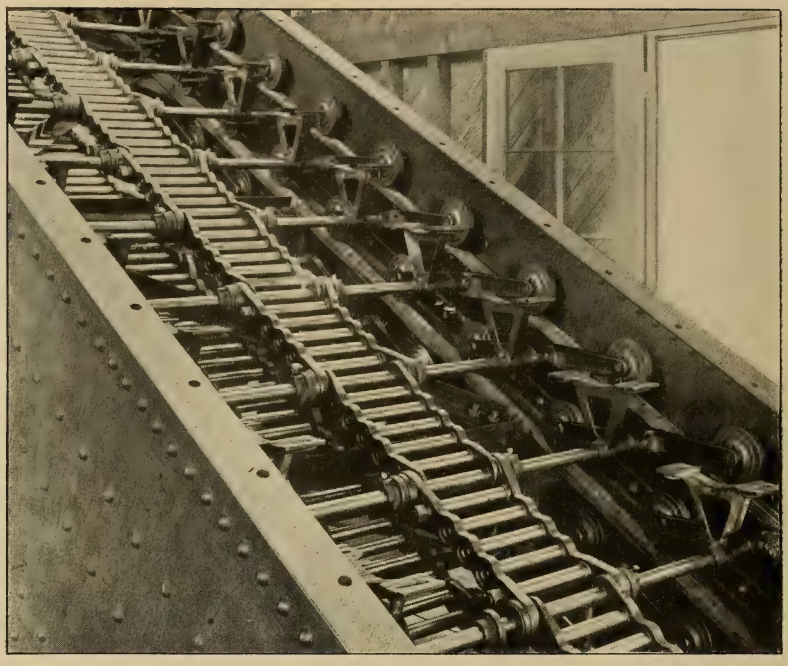
The term transportation facilities embraces necessarily vertical transportation, for it is obvious that the tall building was rendered possible by the development of the elevator system, from its clumsy inception less than half a century ago to the capacious and perfected elevator of to-day, travelling at the rate of six or eight miles an hour through short flights.

Another potent cause for concentration or congestion is the change in business methods, which may be expressed by "quick sales and small profits,"

THE UPPER LANDING OF THE ESCALATOR SHOWN ON THE OPPOSITE PAGE. UNLESS THE PASSENGER STEPS OFF HE IS GENTLY PUSHED OFF AT THE TERMINAL BARRIER

whereby 100,000 people daily throng an establishment, making their purchases from a stock of merchandise embracing countless varieties found heretofore each by itself in as many small shops.

The success of a great retail establishment depends upon the displayed merchandise suggesting "wants" to the visitor,—for the theory of advertising is to procure the visit. It is, therefore, important to bring the largest assortment under the eye of the purchaser. The business is limited to five or six floors of the building, but half or more of the departments are usually located on the main floor, often disadvantageously to a possible maximum business which might be done in each, while on the other floors more than adequate space is allotted to the remaining departments,



A CONSTRUCTION VIEW, SHOWING THE FRONT AND BACK WHEELS AND TRUCKS. THE WHEELS, AS WILL BE NOTED, LIE IN HORIZONTAL PLANES, PARALLEL WITH THE SURFACES OF THE BRACKETS SUPPORTING THE TREADS

and liberal advertising of cut prices at the expense of profits is necessary to induce inspection.

In some establishments a service comprising thirty or more elevators is maintained at great expense; but the limitation to the number of elevators is neither their cost nor maintenance, but is the space occupied by them and their approaches.

The elevator is a machine of reciprocating and intermittent motion, and its capacity is limited by this fact, as will be seen on considering an ordinary elevator in mercantile use, which requires three minutes for the round trip.

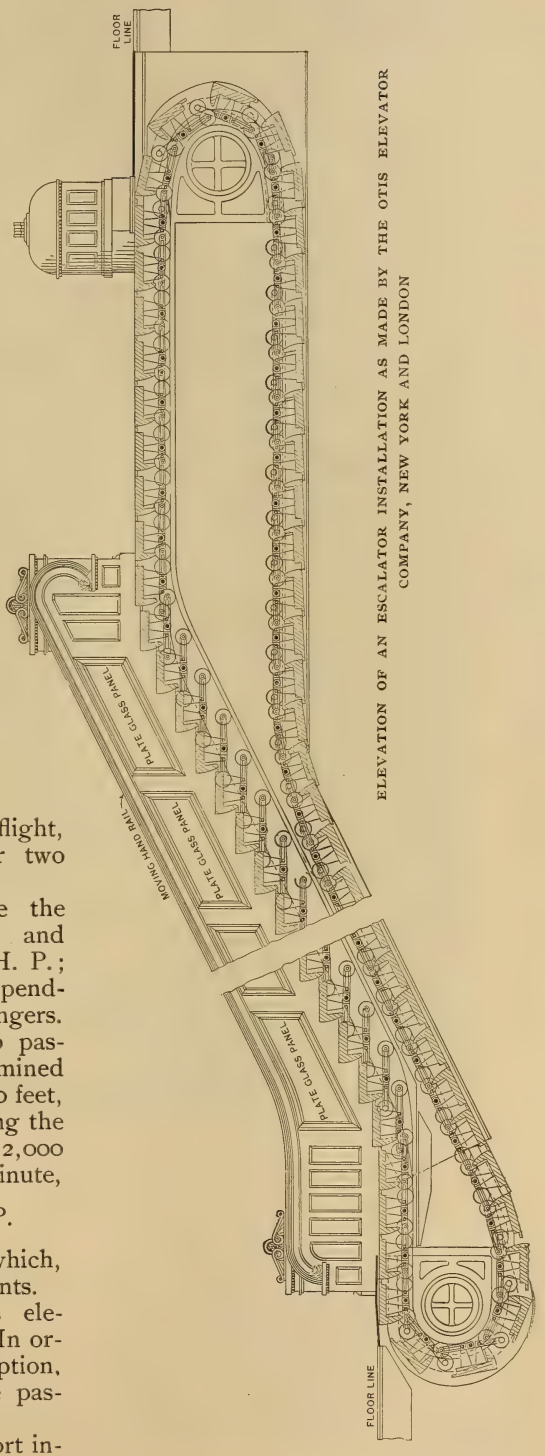
It travels a distance of perhaps, all told, 180 feet at a speed of 6 feet per second, and, therefore, is in motion but thirty seconds out of three minutes. For the balance of the time it is at rest at the various landings. In other words, in a ten-hour day it actually performs the useful work of transporting passengers for less than two hours; during more than eight hours it is at rest, taking on and discharging passengers,—a necessary service, it is true, but nevertheless one which operates against efficiency and is a source of delay and hindrance to the passenger; or, conversely, the passengers are expedited during less than two hours and retarded more than eight hours. The escalator, on the other hand, is in constant motion, with a speed at which the passenger may, with facility, step upon or from it, and in absolute safety.

The first essential of design is to inspire confidence on the part of the passenger, and this reason, if there were no other, determined its form to be that of a staircase,—an architectural feature familiar to all from infancy, and of which no one questions the safety. The escalator is, then, a perfect staircase at all times, and upon it the passenger may stand or walk, in either direction, with the same certainty as upon a stationary stairway, for its motion does not affect equilibrium.

It is not to be supposed from this that,

considered psychologically, the use of the escalator is unattended with sensation. The chief sensation attends stepping on, and, to a less degree, stepping off. It is analogous, though much less pronounced, to the sensation, familiar to all, attending the like act in the case of a slowly moving omnibus or car. After a very few trips upon the escalator all novel sensation disappears, and its use evokes no other than attends the use of a stationary staircase.

The capacity of the escalator is, of course, dependent upon the speed. At the normal speed of 100 feet lineal per minute, 4000 steps reach the landing per hour. The standard step, 18″×48″ tread, readily accommodates three passengers, and the maximum is, therefore, 12,000 persons per hour. A score of ordinary sized elevators would be required to perform this service. The floor space occupied by the escalator, from newel post to head room of 6 feet under the flight, is less than that required for two elevators.



ELEVATION OF AN ESCALATOR INSTALLATION AS MADE BY THE OTIS ELEVATOR COMPANY, NEW YORK AND LONDON

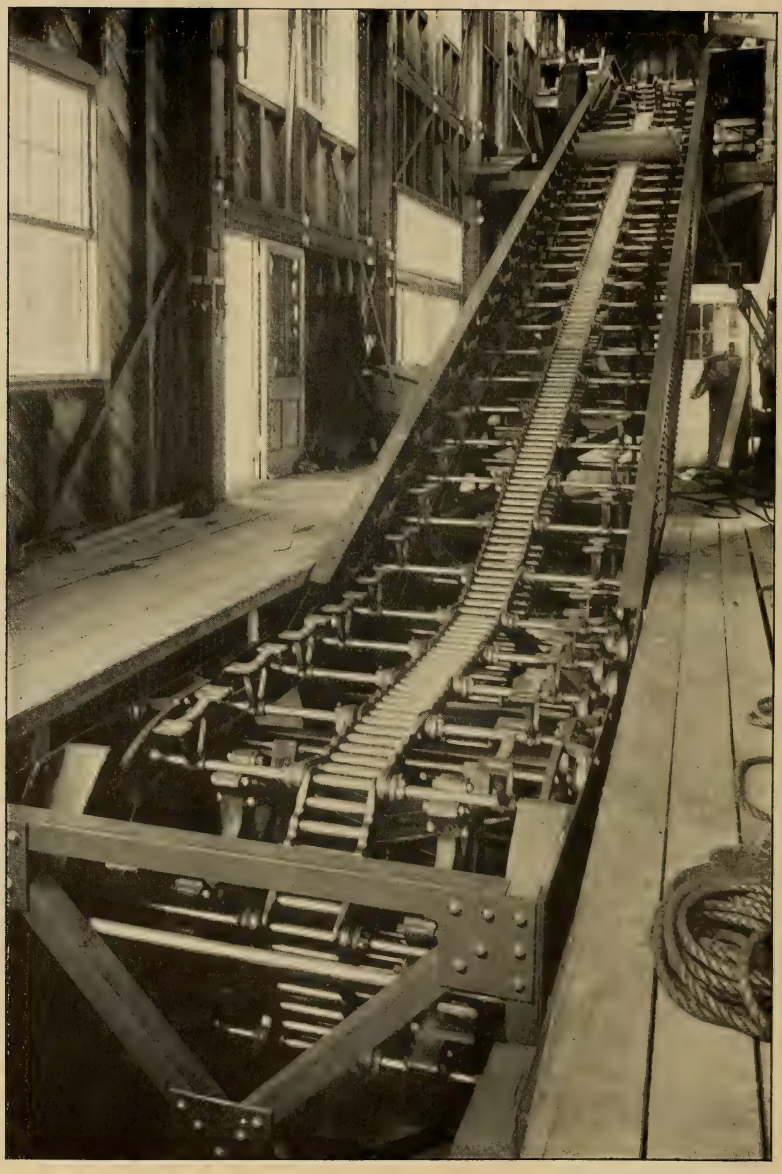
The power required to drive the escalator, including hand rails and shunt, is nominal, less than 10 H. P.; to this must be added the duty, depending upon the number of passengers. For a maximum load of 12,000 passengers, this duty may be determined as follows:—Assuming a rise of 20 feet, and weight of passengers (including the friction) 125 pounds, we have for 12,000 passengers per hour, or 200 per minute,

$$\frac{200 \times 125 \times 20}{33{,}000} = 15.15 \text{ H. P.}$$

15.15 H. P. + 10 = 25 H. P., which, at 1 cent per H. P.-hour, is 25 cents.

12,000 ÷ 25 = 480 passengers elevated at power cost of 1 cent. In ordinary use the total power consumption, including the duty of lifting the passengers, averages about 10 H. P.

It has been found that for short in-



THE RUNNING GEAR AROUND THE LOWER CARRIAGE. OBSERVE THE ASCENDING AND RETURNING RUNS OF THE SPROCKET CHAIN. THE TERMINAL WITH HORIZONTAL RUN FORMS THE LOWER LANDING

tervals the escalator may be taxed to its capacity, but it is obvious that few situations exist where people in such numbers congregate and afford the continuous supply requisite to the maximum capacity of the apparatus. In one large retail store during the holiday season, more than 6000 per hour have been carried upon the escalator for five hours of the day, and the aggregate for an entire day is believed to be 50,000. In the same store on an ordinary day, the passengers alighting at the second floor from the eight large elevators, which run from the basement to the fifth floor, were counted, likewise the number at

the escalator. This latter was found to be 859 per cent. of the number delivered by the eight elevators.

In another establishment, in a very busy hour, the number taken from the first floor by the escalator was four times the number taken from the first floor by the fourteen elevators, which were running at their maximum capacity. To the merchant this spells opportunity for business.

The experience at the Twenty-third street and Sixth avenue station of the Manhattan Elevated Railroad, in New York, during a recent shutdown of the escalator, which has there been in service for some time, is interesting as showing the attitude of the public, of which many millions have been carried by the installation during the several years of its operation. The daily traffic receipts of this station for a period beginning several weeks before the shutdown and extending as many after, for the years 1903 and 1902, and receipts of the adjacent stations for the same period, were carefully plotted, curves established, likewise ratio curves, and the loss area during the period of shutdown was determined. The loss area was found to embrace 64,645 fares. It was, furthermore, daily, a matter of observation that numbers of people, finding that the escalator was not running, refused to climb the stairs, and turned away from the station. Isolated cases were known where the escalator had induced short-haul traffic to adjacent stations, which was discontinued while the escalator was closed down.

In the case of a great store, the escalator may be constructed as one continuous machine, with landings at each floor, and so arranged that steps which carry passengers up may perform a like service later in carrying others down; or separate machines may be installed in various locations affording the best opportunity for displaying merchandise to the customer who may be proceeding from the lower to an upper floor. In the case of a six-story building so equipped with escalator service in both directions, or in all ten escalator flights, it is obvious that the facilities are equal

THE ESCALATOR APPLIED TO TRANSPORTING MATERIALS

to an impossible number of elevators, and as facility of access has a direct bearing upon opportunities for business, it may well be argued that the relative value, measured by rent, of the main and upper floors is greatly changed.

The escalator exhibited by the Otis Elevator Company in the United States Textile section of the Paris Exhibition of 1900 was the first one in public use. It was installed for the purpose of connecting the space on the main floor with the United States space in the gallery, and was in constant operation, carrying many thousands of passengers without the slightest mishap. It was awarded the Grand Prix.

The escalator may be described as a continuous series of rigid steps united by an endless sprocket chain. The chain is composed of two steel shrouds, 18 inches long, placed 8 inches apart and connected by 1½-inch steel pins spaced three inches between centres, thus forming a rigid link; the series of male and female links form the endless chain. The hubs of the links are bushed with bronze bushings with graphite inlay, and, therefore, are self-lubricating; they provide an unusually large surface to resist wear. The axle of the step, which is likewise 1½ inches in diameter, passes through the hub, or joint, of the link, and forms a pin in the chain, giving it the form of a rack of 3 inches pitch, which passes tangentially over the sprocket wheel.

The precision of manufacture, to the thousandth of an inch, makes the chain remarkable, and the result of this accuracy is shown in the perfect alignment of the steps. The axle of the step carries at either end a steel yoke, provided with suitable bearings for two wheels, which are so disposed that they follow separate tracks throughout their entire travel.

Through the placement of the tracks, any desired relation of the steps is secured; on the landings the treads only are in sight, and move horizontally; on the ascent both treads and risers are in sight, forming the familiar outline of a staircase; and on the return, under the ascending flight, the treads all lie in the same oblique plane, presenting the appearance, when the casing is removed, of a belt.

The riser is rigidly attached to the treads, and there are no hinges or joints, as is commonly supposed by those unfamiliar with the details, to account for the disappearance or the reverse of the risers. The step travels with its riser in contact with the edge of the adjacent step, and this relation is maintained as the riser gradually appears or disappears, and then the edges of the tread are in contact, thus avoiding all openings between steps in service. Preferably an electric motor is located within the structure, at the upper landing, and direct-connected with the gearing and sprocket wheel. The step is the unit, and, of course, the replication of the unit is governed by the height from floor to floor. The angle of inclination is 26 degrees, 23 minutes.

The apparatus is noiseless in operation, and this is due to accurate work, and the character of the wheels and tracks. The tracks are of steel and hardwood, insulated from the iron structure supporting them by rubber. The wheels are built up of different metals for the purpose of deadening them, and are practically noiseless. They are provided with means of self-lubrication.

The treads (with the exception of the iron frame) and the risers are of quarter-sawed oak, as are also the balustrades, newels, and paneled casings which enclose the structure. The balustrades, with panels of plate-glass, are flush on the inside, and the steps pass with a clearance of one-thirty-second of an inch. Consequently, it is not possible for a stick or apparel of the passenger to find lodgment. Hand rails, travelling at the speed of the steps, surmount the balustrades, affording positive support to any who may desire it, although it is to be understood it is not essential to the convenient and safe use of the apparatus by the great majority of the passengers. The hand rails are of eliptical form, and are driven by pulleys located at the upper newels. The vari-

ous parts are made by special machinery to absolute dimensions, and are interchangeable. All drillings are located to the thousandth of an inch, and all bolts are finished to the exact size, without clearance. Consequently, when assembled, the apparatus made one of the most remarkable pieces of machine work in the Exposition, and was typical of the best American machine practice.

As shown by the several accompanying illustrations, the beginning and end of the flight are provided with landings which travel horizontally. They are formed of steps with their treads in alignment, and flush with the floor. At the lower landings there is a very gradual transition characterising the change from landing to step form. A given step begins to rise very slowly, thereby disclosing its riser to view. This movement takes place during an interval more than one hundred times that necessary for the correction, constantly applied by all in maintaining equilibrium; it is, therefore, a matter of indifference whether the passenger steps upon two treads or not.

It has been observed that beginners take pains to step upon a single tread, and that after a little experience no attention whatever is given to the footing, owing to the facility of adapting one's self to the situation. The upper landing is somewhat longer, thereby affording an interval for stepping off at either side, of sufficient duration to meet the requirements of the aged and infirm. The sole function of the travelling landing is to provide a time interval to meet the requirement of the slowest-acting passenger, and not of the alert.

The terminal of the exit landing, be it top or bottom (for the escalator operates equally well for either ascent or descent), is a barrier, called the shunt, of which the lower member travels horizontally in a plane oblique to the directions of movement of the steps, and at a speed proportionately greater, thereby imparting a right angle resultant to the person or obstacle on the step which may come in contact with the shunt. By reason of this resultant motion the person or obstacle is gently pushed off the end of the step upon the floor, without shock or injury in the slightest degree.

The motion of the escalator is so smooth and constant that it does not interpose the least obstacle to the free movement of the passenger, who may walk in either direction or assume any attitude, to the same degree as upon a stationary staircase.

A WEAK LINK IN AN ENGINEERING CHAIN

By Francis B. Allen

IN an investigation made by the Hartford Steam Boiler Inspection and Insurance Company to determine the cause of a considerable loss of life and personal injuries resulting from the rupture of a piece of 6-inch pipe in a connection to a steam boiler, the material was gathered for the following note relative to a vital weakness in present methods of dealing with an important engineering detail which the writer deems of sufficient importance to bring to attention, with a suggestion of a remedy. Having in mind an axiom in the engineering profession, that "a chain is no stronger than its weakest link," suggested the title for these remarks.

In boiler inspection we aim to scrutinise all accessible parts carefully to detect defects in material or workmanship while searching for the weakest part; having found it, it devolves upon us to determine, by a conservative estimate based on the application of established rules, what the ultimate strength of the

weakest part is; having ascertained that, we may apply the required factor of safety, according to the requirements of law or rule, and determine what would be a safe load or safe working pressure.

The wrought iron pipe in question was assumed to be of standard thickness for that diameter, and to have been tested at its place of manufacture, according to trade usage, by a hydrostatic pressure of 500 pounds per square inch. Had the material and workmanship been as assumed, the ultimate bursting strength of the pipe, conservatively estimated, would have been about 3000 pounds, giving an approximate factor of safety of twenty at a working pressure of 150 pounds. The required factor of safety of the boiler to which it was attached was only six for the same pressure; hence the strength of the pipe was believed to be largely in excess of what was required. As it failed, however, shortly after being put in service, at a steam pressure of about 120 pounds,—30 pounds less than a hydrostatic pressure of 150 pounds applied about five hours before,—its failure was an unexpected revelation of weakness, and the investigation that followed developed the insecurity and danger of present trade methods respecting pipe and pipe fittings, that should be reformed at the earliest practical moment.

This pipe was one of two comprising the connections to the circulating system from a furnace attachment of a 450 H. P. boiler. The ruptured part measured 6½ feet long by about 7¼ inches at its widest part, and the thickness of the material along the line of rupture was from 0.23 inch to 0.265 inch. It was evident that the initial rupture was in the weld, which, in installing the pipe, happened to have been so placed on the top side as to be in plain view from both the front and back ends of the boiler, and there was ample testimony to the effect that it gave no previous indications of distress or weakness. After the explosion it was found that a part of the weld, for a few inches in length, had not been properly incorporated in the welding process; but it had been covered by a thin film of good material on the outside, so that, superficially, it looked as smooth as the surrounding parts, and gave no indication of weakness. As previously mentioned, it did not leak under a hydrostatic test considerably in excess of the steam pressure at which it failed afterwards, and, strange and unusual as it may appear, there was absolutely no warning, so far as can be determined, preceding the explosion.

A piece of the same 6-inch pipe, about 4 feet long, was cut off next beyond the place of rupture, threaded and capped, and subjected to a hydrostatic pressure of 1800 pounds, when a cast iron flange fractured through a bolt hole. Gauges indicated there was not the slightest distention of this pipe under that pressure. Two rings, about one inch wide, were also cut off from the exploded pipe, one on each side of the defective part that ruptured, and these, subjected to the acid process, showed, except necessary incorporation at the initial point of rupture, an ordinary job of lap welding. Several other tests were also made from other pieces cut from the same pipe, showing the least tensile strength to be 44,650 pounds per square inch, an elastic limit of 29,140 pounds, a reduction of area of 31.4 per cent., and an elongation of 12¾ per cent.

How the defect in the weld occurred is a matter of conjecture. There are several possible ways to account for it:—There might have been a displacement of the ball in the welding process; the strip may have been too narrow to form a 6-inch circle and properly lap at the welding point; cinders, dirt or foreign materials may have been present in the weld or on the ball, preventing proper incorporation of the parts, not, perhaps, sufficiently so to deceive the workman who did the job.

Our investigation failed to show conclusively that anyone charged with a duty in connection with this piece of pipe at the rolling mill or at its inspection had failed to do the part devolving upon him under prevailing conditions and the limitations governing the work. The selling agents who furnished the pipe, merchants of excellent repute in their line of business, testified that they

sold the product of a number of established iron and steel mills, and that the only trade-mark on such pipe was put on with paint in a single place and could thus be easily rubbed off. Not finding that mark, they could not identify the piece or determine the makers.

While the writer would consider it improbable, in view of the defect previously described, that this pipe had been carefully tested at the mill at 500 pounds without revealing the defective weld, it should not be overlooked that such tests are an established detail after the completion of the pipe before it goes into stock, and we do know absolutely that a hydrostatic pressure of 140 pounds, applied after the pipe was in place, a few days before the accident, in connection with the examination made while the pressure was on, revealed defects in the flanges, but did not indicate anything else. It should be noted also that on the day of the explosion, and only a few hours before the accident occurred, a second application of 150 pounds hydrostatic pressure, made in the presence of several persons, gave no indications of weakness, either at the place that subsequently failed, or at any other part; and, furthermore, this pressure at the second time was allowed to remain on the boiler and connections for a sufficient time to enable the inspector and pipe fitter to carefully examine the pipe and flanges. The test gauge meantime showed no appreciable diminution of pressure that would indicate a leak.

While it appears from the foregoing that the mill that produced this piece of pipe was at fault in turning out a dangerously defective piece of work, they escaped the consequences of their act, because there was no means of identification, and the whole fraternity of pipe manufacturers suffered discredit. To remedy this and protect the reputation of the innocent, all pipe product ought to be stamped to indicate the manufacturer as well as the quality of the material, as is done in the case of boiler plates.

At the present time, when there are so many pipes, boilers, and pipe attachments to boilers carrying high-pressure steam, besides in many cases being subjected to an intense heat in the furnaces, it is strange enough that while we take so many precautions to get the best material and workmanship for the boilers, we connect to these boilers in many cases, in even more exposed and trying conditions, pipes and fittings of wholly unknown and uncertain character, instead of being able to protect ourselves or our clients by a stamp of some reputable mill, as a guarantee of excellence.

Current Topics

THE tendency to spontaneous combustion of coal when stored in bulk,—in masses of, say, a thousand tons or thereabouts,—may appear to be a somewhat unusual point to make in favour of the gas engine as a large-size power unit for central station work. It was, however, made as such recently by a central station engineer, whose contention was that the nearly always present danger of spontaneous ignition in the large reserve stock of coal expedient for a power station of any considerable size to carry, to tide over possible temporary interruptions in the supply, from strikes or other causes, was entirely eliminated by the use of gas engines which took their gas from central gas plants. Curiously, however, the fact appears here to have been overlooked that with the large gas engine plant will come, as an almost inseparable adjunct, the gas producer, taking the place of the steam boiler now accessory to the steam engine installation, so that the large coal pile will remain in evidence as before, and the spontaneous ignition troubles as well, even with certain precautions against them, in the way of selecting and storing the coal. Experience in some cases has dictated the safe height to which coal of certain sulphur percentage may be banked, but this height will vary with some other governing conditions easily enough imagined. The gas engine, therefore, will, after all, have to depend for favourable consideration upon its several other well-known good points rather than upon the one mentioned in the opening lines of this paragraph.

THE disastrous Baltimore fire of the past month has brought out most prominently, not the importance of fireproof or fire-resisting structures, as might, at first thought, be supposed, but the tremendous significance of a generous water supply for city fire service. Systems of separate water mains, for such service only, with independent pumping stations, taking water from rivers flowing by, or through, towns, or from adjoining lakes, have thus suddenly become things of absorbing interest in many different places, and preliminary measures have already been taken for installing such systems in some cities where they are now lacking. One plant of this kind, the latest and best existing example, is the one completed for the city of Philadelphia a few months ago and illustrated and described in the lead-

ing article in this issue. Gas engines were determined upon as prime movers in this case, coupled on to large triplex pumps, and the plant, as it stands, is admirably suggestive of what other large cities might find it profitable to duplicate.

REFERRING to the propelling machinery of the famous *Great Eastern*, Sir William H. White, in a recent address to the Institution of Civil Engineers, expressed astonishment that no trace was found in the notes of Brunel, her designer, of any contemplated use of twin screws instead of a combination of screw and paddles. He left so few stones unturned in his search for the best that it is singular to find this arrangement unnoticed. There had been many proposals for twin screws. A design prepared about 1840 by Nasmyth, of steam hammer fame, was for a twin-screw ram with inverted vertical cylinder engines. Moreover, in 1852 Mr. Roberts proposed an arrangement for applying independent engines to each shaft of twin-screw ships of large size, while Mr. George Rennie built and experimented with a twin-screw launch, which was so successful that many others followed. Subsequent experience has shown that, had twin screws been fitted, substantial improvement upon the results obtained in the *Great Eastern* would have been secured, and the great variations in draught of water would have had much less effect upon propulsive efficiency, while the weights of machinery would have been reduced, and the serious inconvenience of an increased breadth of 37 feet over the paddle-boxes avoided.

IT may be well to recall here that the dimensions of the *Great Eastern* were, —Length over all, 693 feet; between perpendiculars, 680 feet; breadth, extreme of hull, 83 feet; over paddle-boxes, 120 feet; depth, 58 feet. Like all the passenger steamers of that period, she had very small erections above the upper deck, and while her gross tonnage was 18,915 tons, her "under-deck" tonnage was 18,837 tons. It was proposed that, as a rule, the draught of water should not exceed 30 feet, corresponding to a displacement of 27,400 tons; but she was capable of being laden more deeply if required. Brunel discussed the case of 32 feet draught, corresponding to about 30,000 tons displacement, and in 1870, when cable-laying, she drew about 34½ feet to 35 feet, with a displacement of 32,700 tons. In order to maintain the average sea speed of 14 knots, it was estimated that from 7000 horse power to 8000 horse-power must be continuously developed. Ample boiler power was provided and arrangements were made by which, for short periods, the power developed could be increased to as much as 10,000 or 11,000 horse-power. At the time of the design,—1852-53,—it must be remembered that the most powerful Cunard steamers were 285 feet long, of less than 2500 tons gross and 5000 tons displacement at deep draught, having 12½ knots sea speed, the engines developing 3000 horse-power. Under these circumstances it was necessary to subdivide the power so that the step required of the manufacturers beyond previous experience should be minimised. Brunel decided to associate paddle wheels with a screw propeller, and to have about 60 per cent. of the total power in the screw engines.

COMMENTING on the size of the *Great Eastern* in his "History of Merchant Shipping" in 1876, Lindsay said:—"It may be, a hundred or fifty years hence, the maritime commerce of the world may have grown to an extent sufficient to justify, with reasonable prospects of profit, another ship of the dimensions of the *Great Eastern*." Little more than twenty years elapsed before the White Star *Oceanic* was designed, to be soon followed by the German *Kaiser Wilhelm II.* and the *Cedric*, all closely approximating to the *Great Eastern* in dimensions and displacement, but exceeding her in tonnage; and now

Messrs. Harland & Wolff have in hand the *Baltic*, nearly 30 feet longer, 4400 tons greater displacement, and 3400 tons gross tonnage more than Brunel's masterpiece in shipbuilding, while still larger ships are contemplated for the Atlantic passenger service.

REFERRING to the statement in the December issue of this magazine, in the article on "Multi-Cylinder Locomotives," that the four-cylinder locomotive designed by Mr. Fred Charles Winby, and known as the "James Tolman," was a failure, Mr. Winby, in a letter of recent date, directs attention to the fact that the engine was not run in Great Britain and was not designed to burn the fuel west of Chicago. Nevertheless, the locomotive did take many goods trains from Milwaukee to Chicago, none with less than 1000 tons behind the engine, and on a line with gradients of 1 in 100 for over a mile in length. Mr. Winby further makes the point that no locomotive designed to burn British coal can be worked with the low-calorific fuel which contains such a large proportion of slag as is found in the fuel used in the western districts of the United States. No British express locomotive, he says, would keep steam with such fuel.

THE only positive result of the much-talked-of high railway speed experiments on the Berlin-Zossen line in Germany has been said to be the demonstration of the not wonderful fact that present roadbeds and track construction are not suitable for speeds above about 100 miles an hour. There probably has not been for some time any serious doubt as to the possibility of attaining speeds above that figure; but the real question,—whether such speeds would be commercially practicable,—still remains unanswered. One factor, of the first importance, in the problem is the resistance of the air, and this assumes a somewhat novel aspect when we have to do with train velocities of over 120 miles an hour, which were reached during the German trials. Concerning this *The Engineer*, of London, remarked in a recent issue: —Air resistance, which is of small import up to 30 miles an hour or so, somewhat quickly assumes larger proportions as the speed rises, and at such a velocity as 120 miles an hour it may be regarded as a principal agent on which power has to be expended. Although little is known with accuracy, it is certain that atmospheric resistance takes a new departure, so to speak, at very high speeds, and assumes proportions which invest devices for reducing it with unwonted interest. It is well to explain here that the bulk or displacement of a train plays a very important part at all moderate speeds. Early in the last century the question of compensating gradients was very keenly discussed. It was held by one party that a railway ought to be made nearly dead level at any cost, while others maintained that rising and falling gradients would compensate each other, and inasmuch as a line with many gradients might be made much more cheaply than one nearly level, the compensating theory figured largely in the committee rooms of the House of Commons; and counsel and engineers fought all the more venomously that they had really no facts to guide them to a right decision. It is now known that compensation occurs only within very narrow limits of speed and inclination. But this is the result of general experience not then available.

IN 1838, however, Dr. Dionysius Lardner, M. de Pambour, Mr. Hardman Earle, and Mr. Edward Woods carried out a series of classical experiments which settled several questions. It was proved that "the atmospheric resistance to railway trains, other things being equal, depends on the volume or magnitude of the coaches." "Cut-airs" were fitted at the back and at the front ends of trains, and were found to be simply innocuous. They did absolutely nothing. The coaches tested were made with sides and ends which

could be taken to pieces and laid flat on the floor. Thus the same wheels and axles carried either trucks or railway coaches. No one has ever disputed the accuracy of these experiments. The trains were made to run down inclines and the speeds noted. There was no chance of error creeping in. They may be taken as conclusive for speeds up to 40 miles an hour. It was found, further, that the heavier the train in proportion to its bulk, the less was the resistance.

In the United States, on the Buffalo and Lockport electric line of the International Railway Company, certain experiments were carried out about three years ago which resulted in showing that a train of two coaches could be run for less power per ton-mile than a single coach, while three cars required less power in proportion than two, and so on. The explanation is that the action of the first coach is to shield those which follow it. To use an American illustration, the second coach is "paced" by the first. The speeds were high. When two cars were coupled, at 75 miles an hour 92 watt-hours per American ton per mile were required to overcome the resistance. But one of these cars run alone would use 137 watt-hours per ton-mile for the same speed. At first sight the facts seem flatly to contradict Lardner, the resistance of the train diminishing with its bulk; for the displacement of two coaches is, of course, double that of one of them. But the contradiction is probably more apparent than real; and it is by no means certain that what is true of a speed of 40 miles an hour must also be true of speeds of 75, 100, or 120 miles an hour. Indeed, engineers appear to be face to face with a new problem; and if the tremendous speeds of which so much has been heard recently are to be adopted in practice, it will probably be found essential to modify the external form of the train in a way which would be totally unnecessary under normal speed conditions. The experiments made by Mr. Boys on the resistance of the air to the flight of projectiles are fairly well known, if for no other reason, because of the wonderful photographs he has taken and exhibited on the screen at the Institution of Civil Engineers. The heaping up of the air in front of a bullet has been made plain to the eye, and it appears clear that something of the same kind must go on with exceptionally high train velocities. It may, perhaps, be found that the best form for a train will be a very much prolonged, closely articulated cylinder, with a sharp bow and stern, possibly a paraboloid. So far, little or nothing has been said about the power expended on the Zossen line. It is understood that it is very high,—so high that it is of the utmost importance that the resistance should be reduced. How this may be effected as regards wheels, rails, and journals is pretty well known. There is reason, however, to believe that there are no available data which will tell the German engineers and electricians what is the form of least resistance for their trains. There is open, therefore, a field of inquiry which ought to give high pecuniary returns for its cultivation.

The erection of the first blast furnace in Africa was recently announced in the *African World*, and according to the particulars there given, the furnace ought to be very nearly ready for business now. It appears that about six months ago great interest was created by the discovery of workable iron ore deposits in the Lydenburg district of the Transvaal, which has since been acquired by Rand capitalists, but transit difficulties have postponed development of the property. In the meantime, the Lydenburg discoveries were eclipsed by the location of rich iron ore deposits within a radius of a dozen miles from Pretoria itself, the railway line actually passing through the property. The territory in question, extending, with adjacent coal fields and other properties, over twenty square miles, was acquired by a syndicate, and in addition to the furnace, which will have a capacity of 500 tons of pig iron weekly, there is to

be a complete installation of rolling mills for the production of rails and merchant sections, and black sheets for galvanising, etc. A steel-converting plant has also been arranged for. By above-ground survey and cross-cutting it has been estimated that about 62,000,000 tons of iron are actually in sight. The ore is of the hematite and magnetic varieties, assaying from 58 to 62 per cent. of metallic iron. The syndicate has acquired an adjacent colliery in full working order, which produces an admirable coal for smelting, whilst abundance of limestone lies close by. An extensive deposit of manganese ore has also been acquired by the syndicate, which proposes to ship large quantities of this ore to England and elsewhere.

In discussing water softening and water softeners recently before the Institution of Mechanical Engineers, Mr. W. H. Maw pointed out one great advantage of such softeners which does not seem to always receive its proper share of attention, and that is the way in which the use of such apparatus enlarges the choice of the type of boiler available for a given service. In the case of works in the country, where there is ample room for putting down, say, Lancashire boilers, or boilers occupying a considerable space, range of selection does not signify so much; but in crowded cities, where boilers of the Lancashire and kindred types are often difficult and expensive to get into boiler rooms,—and where, in consequence, boilers too small for their work are frequently put in,—it is a great thing to have at command a pure water, and to be able to use boilers of the locomotive, Cornish multi-tubular, and water-tube types, which can be readily installed, and which have ample heating surface for their work. The fact of being able to use boilers of this kind is, under such conditions, an advantage quite outweighing any question of the cost of softening.

Just what a paper car wheel is and how it is made is thus told in a recent issue of *Railway and Locomotive Engineering*:—The material of a paper wheel is a calendered rye-straw board or thick paper made specially for the purpose at the company's paper mills. This is sent to the works in various sizes suitable for the dimensions of the wheel centre to be made. The first operation is for two men standing beside a pile of the boards to brush over each sheet a coating of flour paste, until a dozen are pasted into a layer. A third man transfers this layer to a hydraulic press, where a pressure of 500 tons or more is applied. After solidifying under this pressure for two hours the twelve-sheet layers are kept in a drying room heated to a temperature of 120° F. Several of these layers are, in turn, pasted together, pressed, and given another drying. This is kept up until a circular block is formed containing from 120 to 160 sheets, varying from 4½ to 5½ inches in thickness, and as compact as seasoned hickory. The blocks are then turned in a lathe slightly larger than the tire, and the hole is bored for the cast iron centre. In turning, the paper blocks make a shaving that resembles strips of leather. The centre and the tire are forced on under a powerful hydraulic press. The average life of the tire of a paper wheel is about 300,000 miles. That represents about 1¼-inch wear. The centres do not seem to be affected by service, and they are always good for renewal of tires unless some accident happens to them.

The merits of multiple-unit automobile trains, operated by gasoline and electric machinery combined, are at present being exploited on both sides of the Atlantic, French reports giving somewhat meagre accounts of what is called the Renard railless train, while in the United States an equipment of apparently similar make-up was recently exhibited. The French waggon train has been described as consisting of a 40 H. P. gasoline or petrol motor car, hitched on to several waggons; but instead of hauling these after the manner

of a locomotive, it supplies power electrically to each of the vehicles, which are thus self-propelling. Trials between Paris and Versailles are understood to have been made, with encouraging results. The American outfit consists, similarly, of a gasoline motor car and two trailing waggons, the motor car propelling itself and using its surplus power for driving a dynamo for electric current supply to electric motors on the trailing cars. Though it may be presumed that the preponderating merits of thus carrying along with the train a small central power station have been definitely ascertained, it is not very clear what they are. Self-contained units, driven directly by gasoline engines, without the intermediate electric conversions, would seem to come nearer the mark of perfection in several ways, not the least of which would be that of greater simplicity of equipment and management, and that is an important consideration.

As illustrating the analytical character of mind of the late Sir Henry Bessemer and also his quickness of perception, Captain Robert W. Hunt, in a recent lecture at Cornell University, mentioned the following episode in Bessemer's career:—The manufacture of "bronze" powder had been a German secret-monopoly. The process of making was carefully guarded, and the material found a world-wide market. It was prepared from a cheap material, but the process of making was known to be long and tedious. To attack such a problem was well suited to Bessemer's active mind and energetic body. He had spent much money, time and labour,—built expensive machinery to crush to an impalpable powder the alloys which he employed, and obtained a basis for a pigment which was satisfactory; but it was a failure as a paint, because it had no brilliancy,—in fact, not even a suggestion of metallic lustre. He was almost hopeless, when he happened to call on a Mr. De La Rue, the head of a famous stationery house in London, and a scientific man, whose acquaintance Bessemer had previously made in a business way. On this occasion he found him examining samples of flour and potato starch under a microscope, and he explained that they could be distinguished one from the other by the form of their respective crystals. That was enough for Bessemer. Why could not the same thing be used to distinguish between his lack-lustre powder and the brilliant German? The microscope did not fail him, as it showed that his grains were round and uniform, while the German powder consisted of very thin flakes of irregular shape. This demonstrated that the metal must be rolled into the thinnest sheets, and then broken into minute particles, and not ground at all. So he had the courage to throw away all he had done and attack the problem afresh. This he did successfully, and was enabled, after more patient labour, to produce an article costing one-twentieth the selling price of the German,—this because the Germans hammered out their sheets of metal by hand, in the way gold foil was produced.

One of Bessemer's earliest commercial ventures, mentioned by Captain Hunt, seems to have been in connection with manufacture of plumbago, or black-lead drawing pencils. Great Britain depended until some time after 1831 for its supply of plumbago suitable for such pencils upon a single mine located in Cumberland. This was of immense value to its fortunate owners, and was closely guarded and its production limited. It was operated for but a short time each year, when about 40,000 pounds were taken out; then the mine was again tightly sealed. This plumbago was bought principally by a Jewish syndicate for 40 shillings a pound, and by them manufactured into pencils. We are told that this ring was dependent upon an inner one,—the actual cutters of the plumbago,—who with great skill, and with a waste of 60 per cent. and for about 20 shillings a pound, sawed the brittle material into thin sticks. The waste realised only about half a

crown a pound, and the prepared sticks, when ready for the cedar wood cases, were sold at over 80 shillings a pound. There were no lead pencils with rubber-tipped ends for a penny a piece in those days. Young Bessemer seized upon the opportunity. He built a powerful hydraulic press, and bought up all the refuse and waste plumbago he could find, at about half a crown a pound. In fact, he bought up all the available supply in Great Britain. This he ground, lixiviated, mixed with a proper binding material, and by his powerful hydraulic press formed into compact slabs which were subsequently cut with fine saws into proper sized sticks that were equally as good, if not better, than those made direct from the ore. He could undersell, and so controlled the market.

THE choice of reliable commercial representatives in the Far East is not an easy thing, but the necessity of having such representatives is beyond question. Even in cases where business is done directly with firms, it is said to be advisable to employ a representative at the same time. There are a thousand and one details which require attention and which cannot be properly attended to by long-distance correspondence. In a recent special consular report we are told that the right kind of representative to engage depends largely upon the nature of the goods in which business is to be done. If a business is to be conducted upon a wholesale plan, it is wisest to try to engage a "big representative," who has been in the business for a long time and can show unmistakable proof of business integrity. Generally it will be found difficult to engage such a person, or such representative firms, because very frequently they are already in the service of some prominent competitor who came first upon the field. Then also they are, as a rule, crowded with work, as men with unblemished reputations, who are capable of running a large wholesale business in the Orient for a European exporter, are rare and cannot be picked up every day. But it is said that though these big representatives may be reluctant to undertake any more European business, if they can be prevailed upon to do so, great confidence may be placed in the results. Business may pick up but slowly at first, but there is no need to worry about the execution of contracts.

IN case of articles which are to be pushed in the markets upon a small scale, and mainly in the retail trade, the engagement of some smaller representative is said to be advisable. It is especially in such cases that great circumspection is necessary in making a choice. While it may be comparatively easy to choose a reliable agent among the largest firms of the place, this is not the case where smaller firms are under consideration. Many of these have been upon the blacklist for years, but manage to cover up their tracks so shrewdly that the unsuspecting are easy prey, and even the most circumspect tread on dangerous ground. If great care is taken, one may find a firm of young men who are reliable, enterprising, and energetic.

THESE facts ought to be sufficiently plain to show that Oriental representatives cannot wisely be engaged through the mails and without the most scrutinising investigation. To strike a choice among those who offer themselves through correspondence is the height of folly, unless they are in a position to produce indisputable evidence of their responsibility and integrity, preferably guaranteed by some well-known and prominent eastern firm which has consented to act as a sort of protector. The eastern buyer is known to possess unusual natural keenness and business ability, and when he combines with this a bent to trickery and sharp practice he becomes a dangerous man to deal with through long-distance correspondence.

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THE LATEST PORTRAIT OF THOMAS A. EDISON

FROM A PHOTOGRAPH TAKEN BY FALK ON FEBRUARY 11, 1904, THE FIFTY-SEVENTH ANNIVERSARY OF EDISON'S BIRTHDAY

CASSIER'S MAGAZINE

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THE HIGHEST RAILWAY OF EUROPE

FROM THUSIS TO ST. MORITZ, SWITZERLAND

By Enrico Bignami

APPROACHING THE LANDWASSER VIADUCT. SEE PAGE 480

DURING the past year a new railway system has been opened to the public in Rhaetia, Canton Grison, Switzerland, which reaches at one point an altitude of 5980 feet, the highest point on any railway on the European Continent. The entire system is 107 miles long, the gauge being uniformly one metre. The portion from Thusis to St. Moritz has only recently

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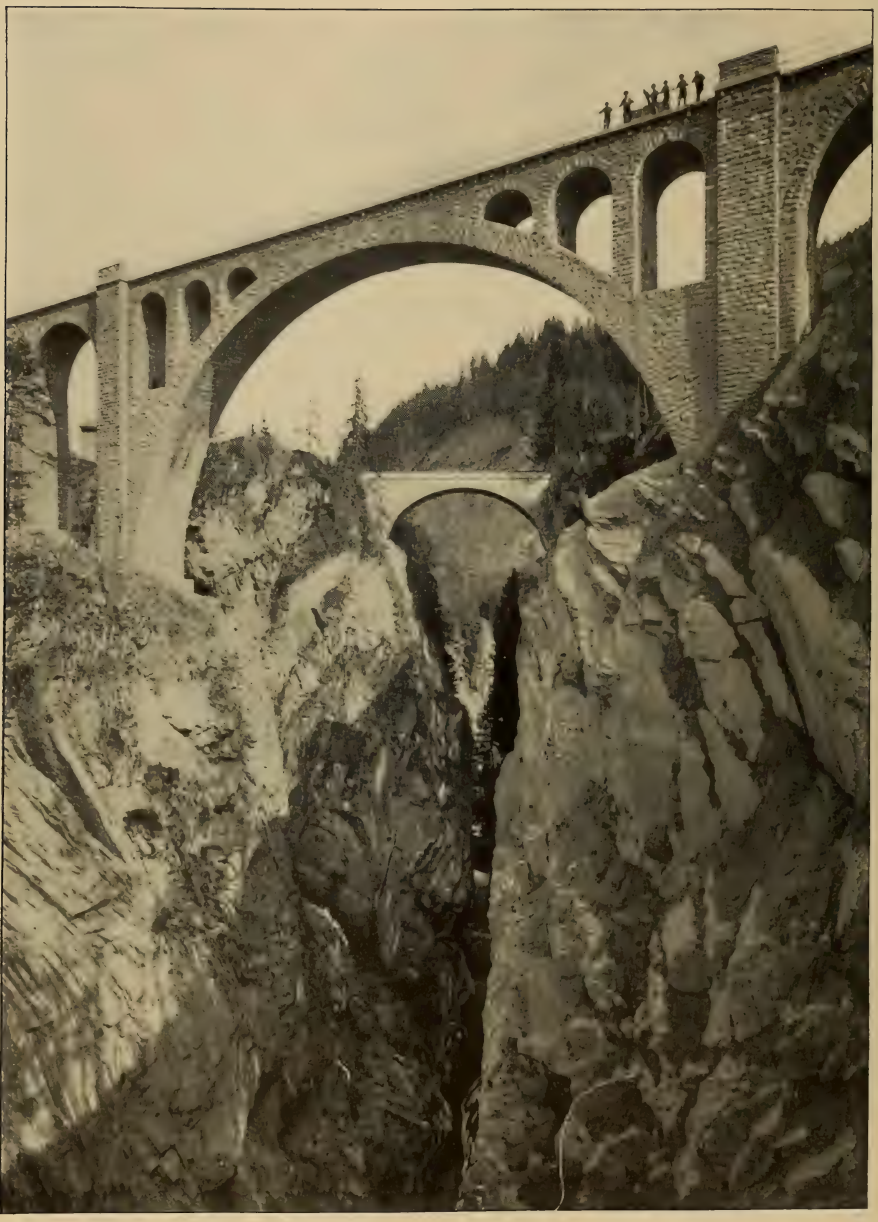


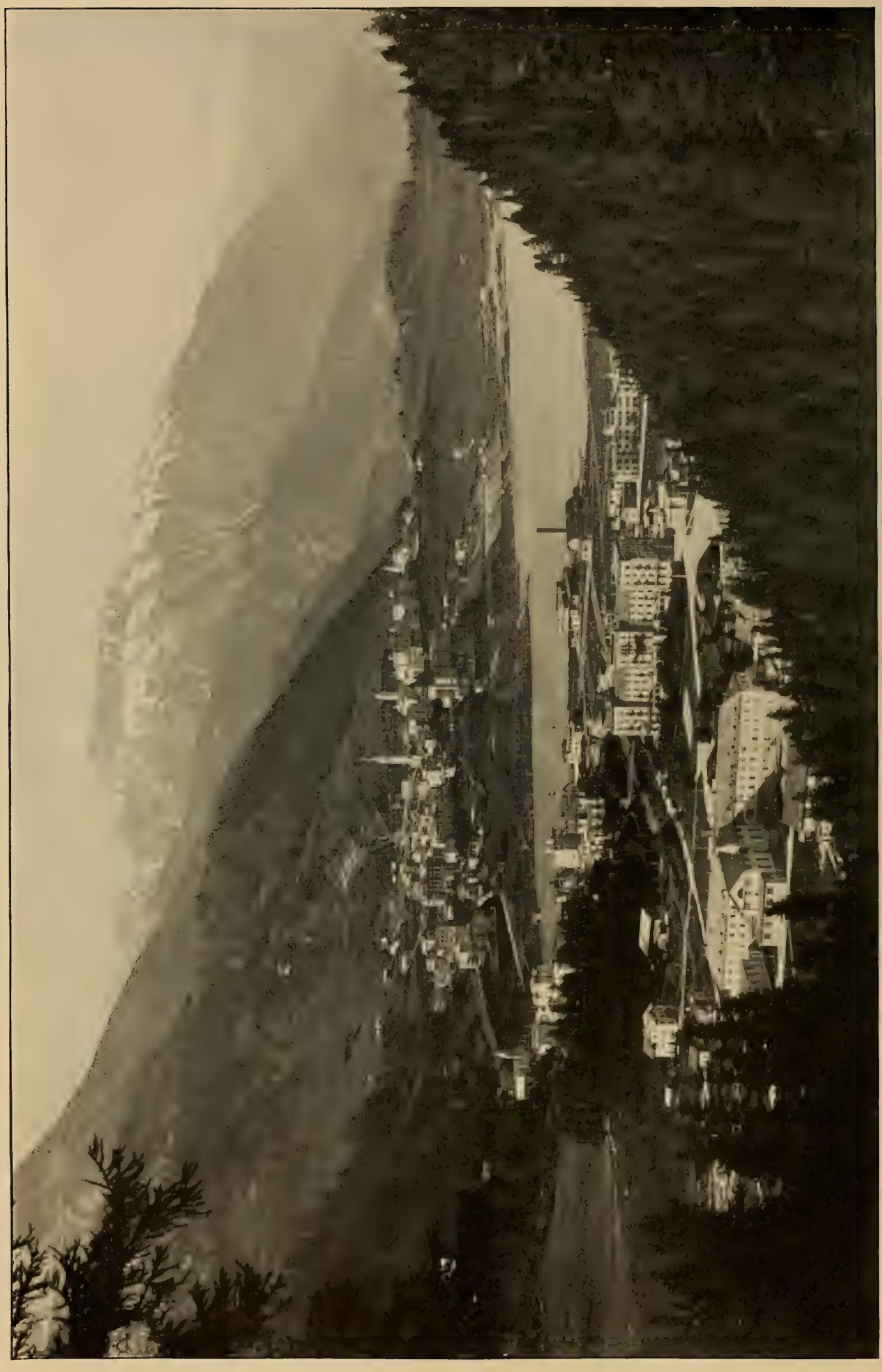
THE SOLIS BRIDGE

been completed. This section, about 39 miles long, has been called the Albula Railway, as it follows the windings of a tributary of the Rhine of that name for nearly its entire length, and it is with this particular line that we are here concerned.

But few railways can compare with the one to be here considered in point of beauty of scenery and of engineering difficulties encountered in construction. This alone would make it an object of interest. But it is further noteworthy on account of its probable future important bearing on the commercial intercourse between Italy and Switzerland, and also between Italy and Bavaria, as well as the rest of Germany. For as soon as the two first-mentioned states will have reached some agreement concerning railway communication between Chiavenna and St. Moritz via Maloggia and between Tirano and St. Moritz via the Bernina, the Albula Railway will step from the position of a purely local line to one of international importance. Among all the Alpine regions, the Canton Grison stands in many ways pre-eminent. Although but sparsely inhabited, it is probably the most extensive and the most fertile of Switzerland. At 7000 feet above sea-level we find fertile meadows, from which rise snow-capped mountains, with innumerable brooks rushing on to the rivers below. The village of Coira is surrounded by these high peaks and picturesque valleys, in whose shelter are located many large hotels and sanitariums known to the entire civilised world. And of all the valleys of Grison, the Engadine is the most beautiful and the most important. In fact, owing to its large extent, its admirable climatic conditions, its fertility, its entrancing scenery, and all that man's handiwork has added to these, it may be counted among the most enchanting of Europe.

A VIEW OF THUSIS, THE LOWER TERMINAL

Besides being thus blessed with natural beauty, the mountains of Grison, and especially those of the Engadine, are rich in mineral springs, which chem-



ST. MORITZ, AT THE UPPER END OF THE LINE

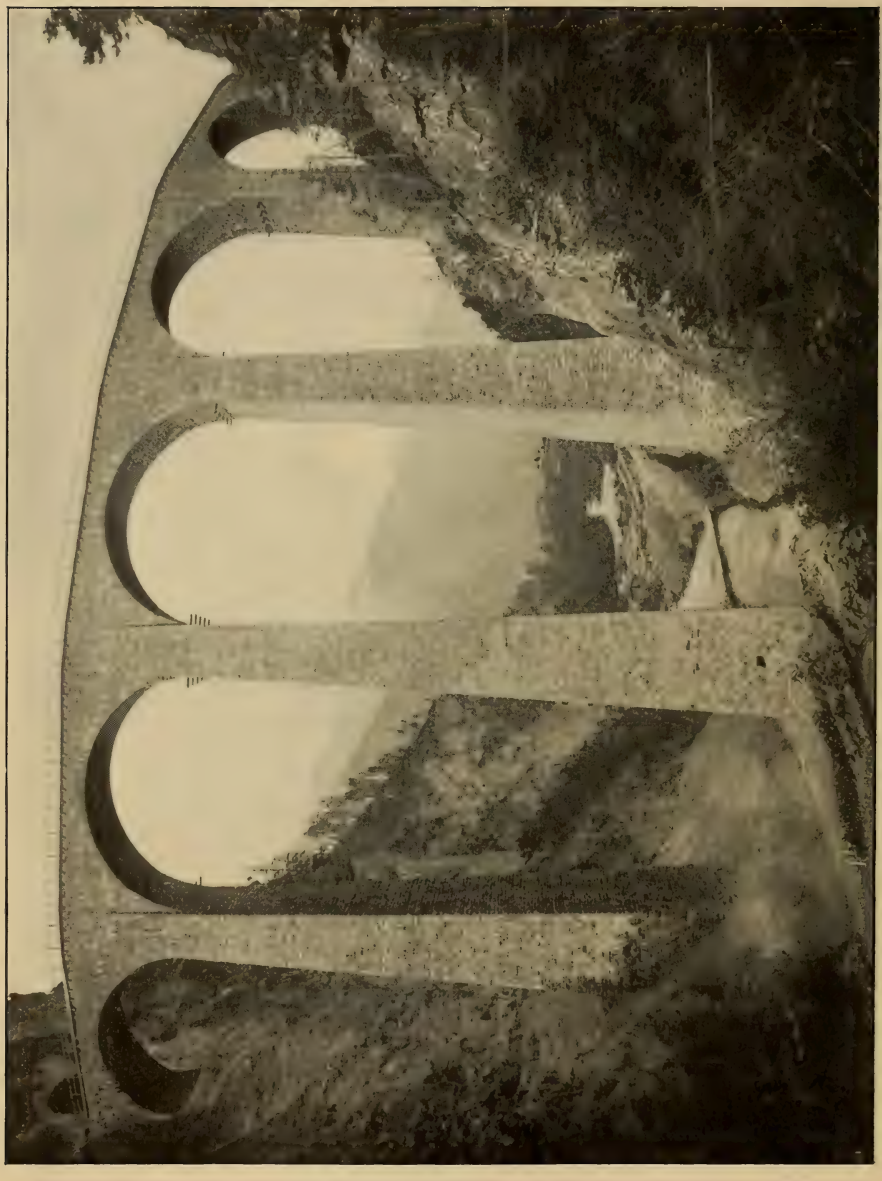
ABOVE FILISUR. HERE THE ALPINE SECTION OF THE LINE BEGINS

ical analyses have characterised as of the highest value in combatting various known diseases. When it is considered that up to quite recently this territory, so rich in all that attracts pleasure and health seekers, has been accessible only on foot or by waggon; that not until the construction of the Albula Railway was an easy path of entrance at hand, it can readily be seen that the new line, even ignoring its ulterior possibilities, is of no mean importance.

Starting at Thusis, the lower terminal, we ascend at first a short grade of 2.5 per cent. toward the Rhine, after crossing which we are carried along a high embankment above Sils to the station of that name, across the plateau of Campi, and through a short tunnel underneath the picturesque ruins of the castle of the same name, until finally we enter the "Schyn-Schlucht" (gorge of the Schyn) proper, crossing here a number of viaducts and bridges. The station Solis is reached next, which does duty for the villages Untersolis, Mutten, Stuervis, Obervaz, and Alvaschein, being nearest to the first mentioned.

Immediately after leaving this point the cañon of the Albula is crossed near the highway bridge, on a stone bridge 492 feet long, the main arch measuring 138 feet. This, it may be mentioned, is the most beautiful and most important bridge along the route. A short, level section of 2950 feet is next traversed, after which the line again approaches the Albula, whose windings it follows over numerous bridges and through several tunnels as far as the station Tiefencastel.

The section Thusis-Tiefencastel, approximately nine miles long, comprises fourteen tunnels, with a total length of about 130 feet, and sixteen bridges, with a total length of 4163 feet. From Tiefencastel the line continues over a high embankment, whence a beautiful view of the village may be obtained, and then across comparatively level country, with grades varying between 1 and 2.5 per cent., to the



THE LANDWASSER VIADUCT

Schmittentobel, which is crossed on seven arches, each 49 feet long, the highest of them being 115 feet. A short distance beyond, the wild gorge of the Landwasser is spanned by a bridge at a height of 197 feet. This is 492 feet long, and comprises six arches of 66 feet each. Soon thereafter we enter a short tunnel 712 feet long, then wind around the beautiful hill Clavaduera, and finally reach the station Filisur. Between Filisur and Tiefencastel there the tunnel, the road continues up a slight grade as far as Heizenberg, where an extensive view of the Albula valley may be had. Beyond Heizenberg we pass first through several short tunnels, then through one 1348 feet long, bored through the rocks of Berguennerstein, and, emerging from this, we enter the beautiful valley of Berguen, where the station of the same name is located.

From this point, 4514 feet above sea-level, to the next stop, at Preda, which

ONE OF THE TUNNELS NEAR FILISUR

are two more stations of minor importance, Surava and Alvenen, the latter giving access to the well-known hot springs of the same name.

At Filisur commences the Alpine section proper, with a maximum grade of 3.5 per cent. In spite of this heavy grade, it was necessary to construct a helical tunnel directly above Filisur in order to reach the required altitude within a reasonable distance. In this way the line rises rapidly to 558 feet above the level of the valley. Leaving has an elevation of 5879 feet, the distance along the highway is only about 3½ miles, while the railway, in order to overcome the 1365-foot difference in altitude without exceeding the maximum permissible grade of 3.5 per cent., has to traverse, in round numbers, 7½ miles. Contrary to what might be expected, however, we find fewer tunnels and viaducts here than on the previously described section from Thusis to Tiefencastel. On the other hand, there are, perhaps, more curves here than on any

A STATION. AT SAMADEN

other part of the route. The traveller obtains here some of the grandest views of this romantic country with its savage scenery, and also of the imposing features of the railway itself. On this particular section the valley of the Albula is crossed four times on high bridges (among others, that of Muesttail) in a run of about half a mile.

Between Berguen and Preda there are nine tunnels, with a total length of 9725 feet, and nine bridges and viaducts, with a total length of 2237 feet. The most important viaduct is that over the Val Tisch, which is 164 feet high and has four spans of 66 feet each.

Immediately beyond the station Preda is the mouth of the Albula tunnel, which is 19,246 feet long. It opens on the valley Bevers, near Spinas, at 5964 feet above sea-level. In this tunnel the highest point of the line is passed at an altitude of 5980 feet.

Leaving Spinas, the road descends to the station Bevers, the steepest grade being one of 3.2 per cent. This entire distance is covered on a high embankment. The station lies between the village of the same name and the Beverin. From Bevers to Samaden, Celerina,* and finally St. Moritz, nothing of special interest is to be noted, as this entire length lies in an open valley, except for a short distance in the "Charnaduera-Schlucht" below the falls of the Inn, where a few short tunnels are encountered. The steepest grade of this section is one of 2 per cent. On the other hand, although of little interest to the engineer, the tourist will find this part of the run one of the most attractive along the route, as it offers many beautiful glimpses of the mountains and of the valley which they encompass. Just before reaching Samaden, the entire range of the Bernina comes into view. Directly beyond, the train emerges from the "Charnaduera-Schlucht" into open country, and here the charming village St. Moritz, with its lake, its many hotels and baths may

*At Celerina the proposed railroad from the lower Engadine across Mt. Bernina is to start. Joining on to the Rhætische Bahn at this place, the new line will touch, by means of short spurs on the one side, the important town Samaden, and on the other St. Moritz. It will then cross the mountain, and, taking in Poschiavo, it will have its terminal at Tirano, which city is soon to be connected with Brescia by rail; it is now in contact with Sondrio, and, beyond that, with Milan.

ON THE ELECTRIC TRAMWAY AT ST. MORITZ

be seen to the best advantage against a background of snow-capped mountains.

It is but natural that the great beauty of scenery, combined with the healing qualities of the many springs of the locality, should every year attract numberless tourists to the Engadine, and especially to St. Moritz, which is particularly in favour owing to its great altitude of 6070 feet. During three months of the year, indeed, the valley swarms with visitors from all parts of the globe. Here, at the side of eternal snow, a large town, equipped with all the comforts of modern civilisation, has been founded and has flourished. While ordinarily at an altitude of 6500 feet there is profound solitude, where even the song-bird is lacking, and we find only the shepherd and his flock and an occasional cabin, we have at St. Moritz a multitude of imposing hostelries and countless villas scattered over the hills and the plain.

St. Moritz is further blessed in that the proximity of the rivers Inn and Julier furnish ready sources of electric power. During the period from 1886 to 1891 two electric light stations were erected. A little later a system of electric street railways was installed, the operating current being taken from one of these stations.

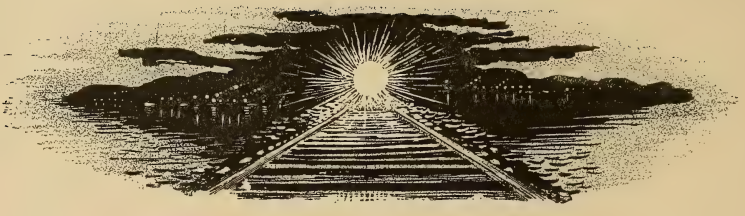
Two months before the Albula Railway was completed the "Société du Réseau de la Rhétie" opened the line Reichenau-Ilanz to the public. This line is 11.8 miles long; its maximum grade is 1.4 per cent., and its minimum radius of curvature, 328 feet. Beginning where the line Reichenau-Thusis ends, which enters the town on a bridge across the Upper Rhine, the road under consideration crosses the Lower Rhine on a steel bridge 279 feet long, and follows the gorge of the latter river until a deep cut carries it through the old Flimser Bergsturz. Above the mouth of the Rabiosa the Rhine is recrossed, the road running on the right hand side of the river from there to Ilanz.

Just below Kæstris the gorge opens out, forming the broad valley Gruob. There the formation of the ground is more favourable, so that, with the exception of a steel bridge of 121 feet span across the river Glenner, nothing of

special interest is to be noted. The station Ilanz is the present terminal; it is proposed, however, to extend the line up the valley of the Rhine to a junction with the St. Gothard Railway.

A feature of the railway from Reichenau to Ilanz is that along the greater part of its route it does not actually touch any of the places on which it draws for its traffic. The topography of the country has made this impossible, as it has also precluded laying the track directly along the banks of the Rhine, on the left as well as on the right hand side of the river. Neither the one nor the other could be accomplished without introducing excessive grades and largely increasing the costs of construction. At the same time, the railroad touches both banks alternately, and in this way constitutes a connecting link.

At the present time the conversion of the motive power of the lines to electricity is under consideration.



THE MODERN DEVELOPMENT OF DOCKS

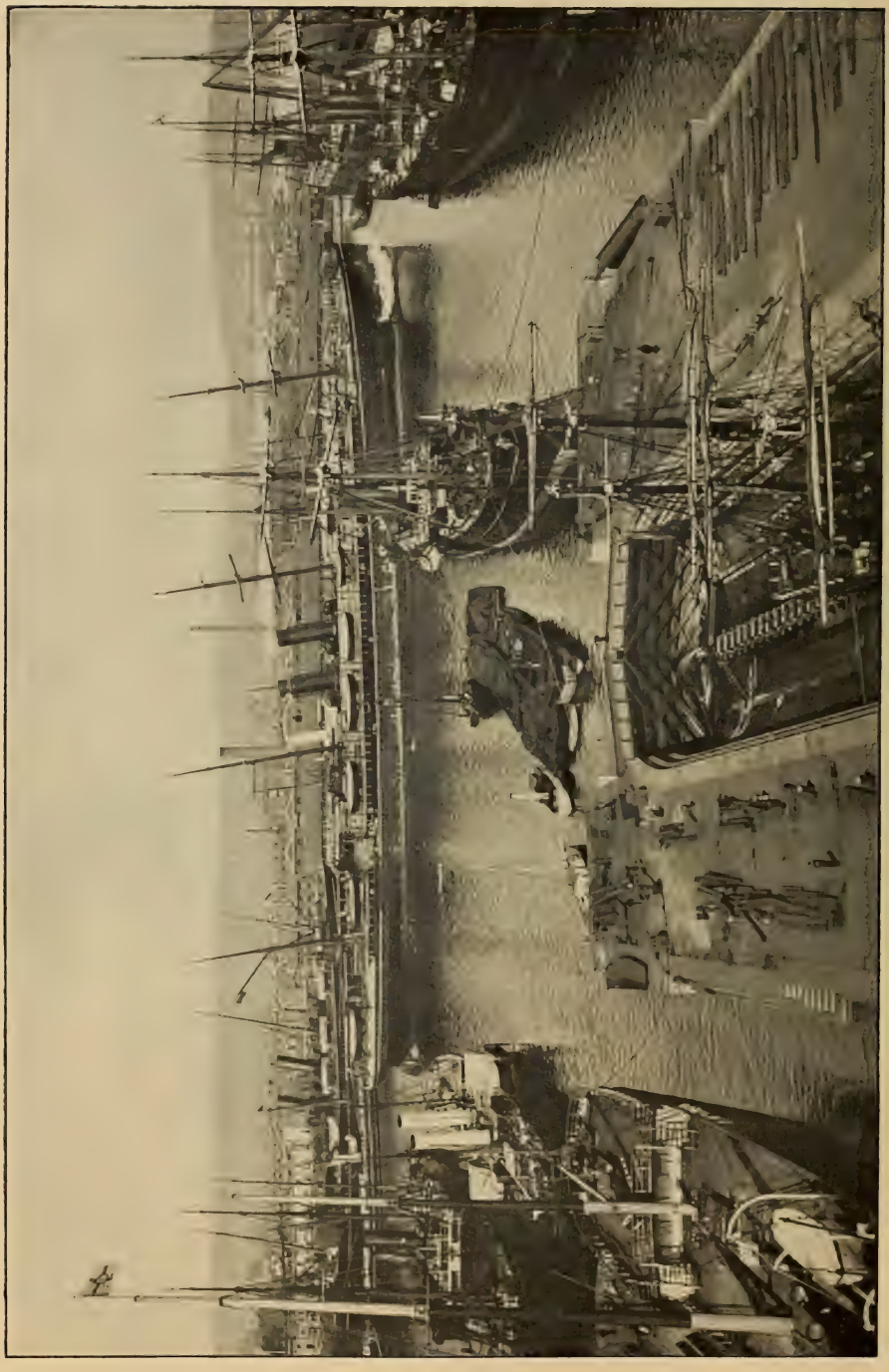
By Brysson Cunningham, B. E., Assoc. M. Inst. C. E.

DOCKS constitute so prominent a feature of most British and Continental ports at the present day that some account of their origin and recent development can scarcely fail to be of interest. Especially will this be the case in a country like the United Kingdom, where no portion of the interior is distant more than seventy miles from the sea coast, and where intercourse with other nations can be maintained only by means of oversea traffic. Under such circumstances the provision of accommodation for shipping naturally is, and indeed always must have been, a matter of public and national concern. The commercial prosperity of the country manifestly depends upon its maritime enterprise.

The question of accommodation, however, is not the only one requiring attention; there is the equally important problem of expedition. In these days of rapid transit and still more rapid communication, it is essential that as little delay as possible should be incurred in the operations connected with the loading and discharging of cargoes. Any avoidable detention of a vessel in port represents to her owners a sum of money, far from inconsiderable, unprofitably expended in wages, stores, maintenance and interest. The situation has been rendered even more acute by recent international rivalry. Ocean-passage records have been reduced to such a degree that any further saving of time has become a matter of minutes rather than of hours. Such keenness of competition obviously demands equal celerity in berthing operations, and, accordingly, it is not surprising to find that very serious attention is being directed to the condition of the most noted ports, both at home and abroad, with a view to improving to the utmost their accessibility and accommodation.

With the former of these desiderata we do not propose to deal in this article; our concern for the present is in regard to the latter.

Accommodation for shipping in ports is provided by three systems, sometimes singly, sometimes conjointly, dependent largely upon local considerations. These systems may be briefly classified as open quays, tidal basins and wet docks. The term dock has been applied to such a variety of uses in connection with maritime engineering that it is necessary to explain that its use here is restricted to its more essential and most common signification, of an enclosed area of water which can be cut off entirely from external communication, for periods of greater or less duration. The necessity for this function is due to tidal action, the range of which is so great, attaining, as it does, a maximum of 40 to 50 feet in the Bristol Channel, as to involve, in many cases, an insufficiency of draught at low water for the flotation of even the smallest craft. In olden times, when vessels were built with stout hulls and substantial keels, this was not a consideration of much importance, and, indeed, we find that one of the advantages claimed for the port of Bristol two centuries ago was that the harbour



SOUTHAMPTON DOCKS

afforded a "soft bed, suitable for the grounding of vessels." Nowadays the attenuated plating of an ocean steamer would inevitably undergo serious strain, if not structural collapse, under such drastic treatment, and hence the necessity for areas of impounded water wherein such vessels can remain afloat at any stage of the tide.

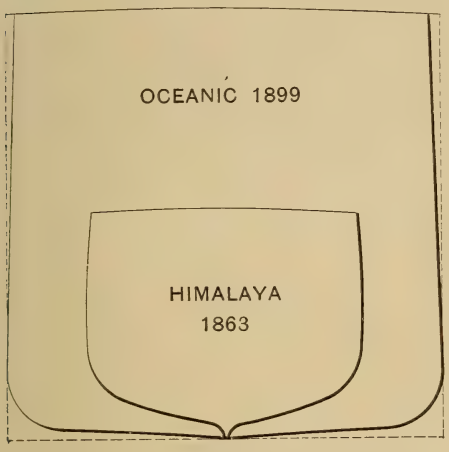
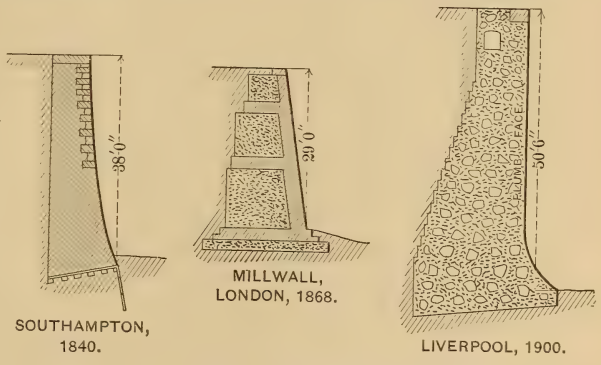


FIG. 1.—TYPICAL MIDSHIP SECTIONS OF VESSELS

At other ports the range of tide is not so extensive and does not entail consequences of so serious a nature. In the absence of any possibility of grounding, the only inconveniences to be endured will be those involved in frequent attention to, and alterations in, the moorings, with the risk of vessels chafing themselves against the quay side, and some interference with the regular discharge of cargo, owing to fluctuations in the water level. Very often, and especially in cases where the tidal range does not exceed 10 feet or so, these inconveniences have not been held of sufficient moment to justify the expense incurred in providing gates and machinery for a closed dock. Furthermore, there is less restriction in the arrival and departure of vessels, and this, as has already been pointed out, is a consideration of no little importance. Accordingly, tidal basins, more or less enclosed, but with entrances always open, constitute the system adopted at a number of ports. These also are commonly included under the generic name of docks, though, strictly speaking, they belong to a separate class.

Open quays are subject to the same inconveniences as tidal basins, with the additional one of being in many cases incapable of much extension. The length of quayage can rarely, if ever, be expanded without loss of concentration, and certainly not to an extent commensurate with the accommodation afforded by docks and basins. Centralisation of traffic within defined and compact limits is a desideratum on several grounds; but, except in small ports, it cannot be attained under the open quay system.

The principal reasons which operate against the general adoption of wet docks may be summed up as (1) the expensive apparatus required for opening and closing their entrances, and (2) their intermittent accessibility. The first of these objections is counterbalanced by the advantages accruing to a quiescent area unaffected by waves and storms, and the second is modified to a very considerable degree by the addition of entrance locks and vestibule basins with deep sills, through the medium of which vessels may be received to a very late period of the ebb tide, if not uninterruptedly.



FIGS. 2. 3 AND 4.—TYPES OF DOCK WALLS.

A VIEW AT THE PORT OF LIVERPOOL, SHOWING THE WHITE STAR LINER "OCEANIC" AT THE DOCK ENTRANCE.

FIG. 5.—TILBURY DOCKS.

Chronologically, no doubt, tidal basins succeeded open quays, primarily in the form of harbours, though it is difficult to establish any definite priority in the matter. There are indications of artificial harbours extending back, beyond the days of Venice, Rome, Carthage and Athens, to the age of Tyre and Sidon. Wet docks, on the other hand, are a comparatively modern innovation. The earliest foreign "pent water" of which there is any mention is a certain "famous Bason of Dunkirk,"—probably the Bassin de la Marine, brought into existence at some date between 1678 and 1706. The first to be constructed in Great Britain was, apparently, the Howland Great Wet Dock on the Thames, concerning which there is documentary evidence of its existence in the year 1703, and, inferentially, for some short time previous thereto. It was followed by the Old Dock at Liverpool in 1709. Some authorities, however, notably Gore's Annals of Liverpool, place the inauguration of the latter

ANOTHER VIEW OF LIVERPOOL DOCKS

in 1700, in consequence of which the assumed precedence of London has been vigorously contested.

However the point may be decided, it is indeed strange to find that during the ensuing eighty or ninety years, despite a very material development in the means of internal communication, dock construction remained very nearly at a standstill. Up to the last decade of the eighteenth century London possessed only its one dock, devoted to the whaling trade, while Liverpool had but three, and these of inconsiderable extent.

The Victorian era brought about a great and striking change in this respect. The discovery of steam as a motive power and the opening up of colonial territory, with the consequent rapid growth of commerce, led to a vigorous revival in maritime engineering operations, attested by the array of over 300 docks and harbours which line the British coast to-day. Liverpool alone has 62 docks and basins, with a total water area of 558 acres and a lineal quayage of 35 miles. London possesses 30 docks, generally larger in size, and covering a total water area of over 570 acres.

Since docks are built for the accommodation of ships, obviously their development will depend upon, and be governed by, the principles underlying the practice of naval construction. It is important, therefore, to review the very radical changes which have taken place in the design of vessels during the last fifty years. The graceful, curved profile amidships and the deep keel of a generation ago have now given way to a square, box-like section, with a flat bottom and with sides perfectly upright, or having an inward inclination towards the top. These features, exhibited in Fig. 1, in which the outline of the *Himalaya*, of 1853, is contrasted with that of the *Oceanic*, of 1899, obviously demand quays with perpendicular faces and entrances with level sills. The effect is apparent in Figs. 2, 3 and 4, which are sections of dock walls at Southampton (1840), Millwall (1868), and Liverpool (1900), respectively.

The average length of ships has increased some 50 or 60 per cent. during the last quarter of a century. The 455 feet of the *Britannic*, of 1874, seem almost insignificant compared with the 702 feet of the latest White Star liner *Cedric*, and the 760 feet of the projected Cunarders. The 1000-foot vessel will assuredly not be long in coming. Berths are even now being devised to accord with this standard, and entrance locks and graving docks are also being lengthened. A few years back 500 feet were considered an extreme dimension; nowadays this is deemed very moderate. The length of an entrance lock does not, of course, absolutely limit the size of

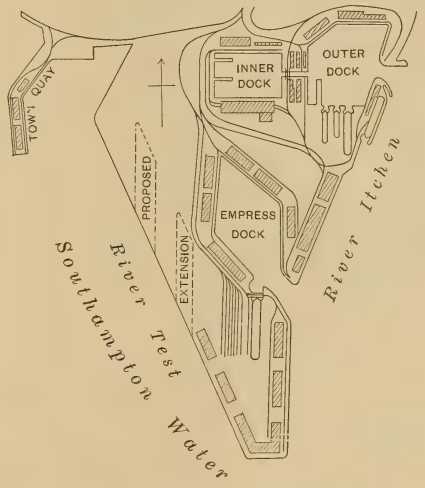


FIG. 6.—SOUTHAMPTON DOCKS.

vessels using the dock, because vessels of any length may enter about the time of high water, when, for a period of an hour or two, the gates are generally kept open throughout; but it affects the accessibility of a dock, since, after the expiration of that period, vessels wishing to enter can only do so by the process of locking. The largest lock on the Thames is the Tilbury entrance lock, 700 feet long, followed by the northern entrance lock of the Albert Dock, 550 feet long. The largest lock at Liverpool is 602 feet long; at Barry there is a lock 647 feet in length; at Barrow, one 700 feet; at Cardiff, one 800 feet. Swansea also

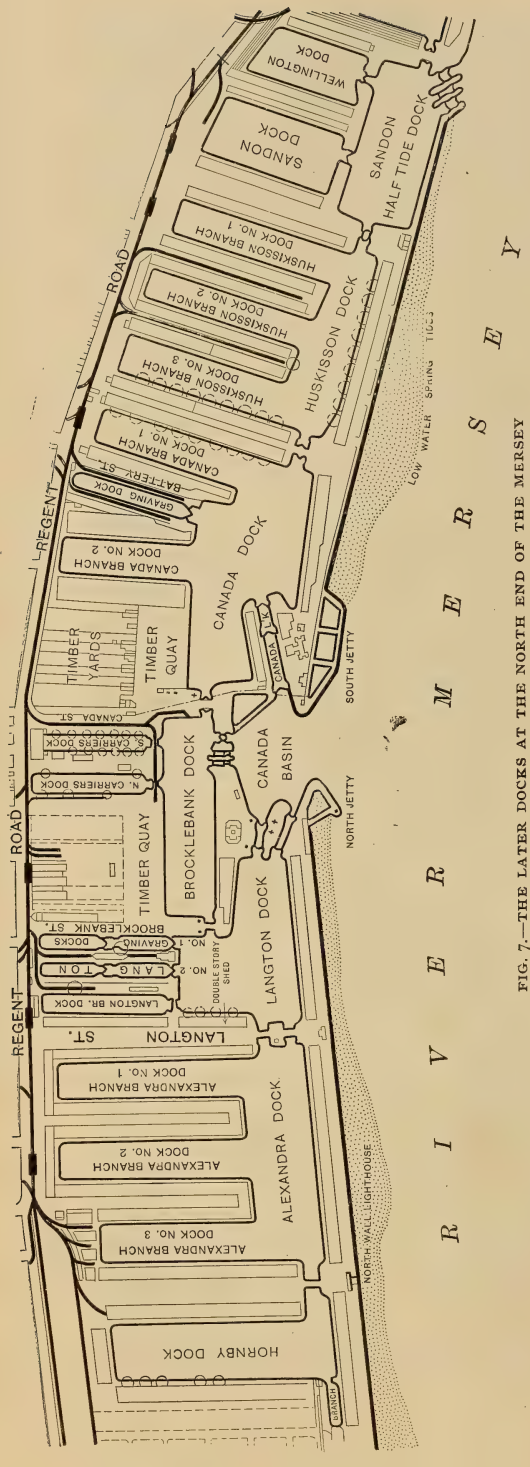


FIG. 7.—THE LATER DOCKS AT THE NORTH END OF THE MERSEY

has an 800-foot lock in hand. Of graving docks there is one of 800 feet at Southampton; one of 846 feet at Tilbury; of 867 feet at Barry; of 880 feet at Glasgow (Govan); and of 925 feet at Liverpool.

The beam of ships has increased more rapidly than the length. The beam of the *Britannic* was 45 feet, and a ratio between length and breadth of about 10 to 1 was maintained fairly well until ten years ago, when the *Campania* was built with a breadth of 65 feet to a length of 600 feet. At present the dimensions exhibited in the *Cedric* and *Celtic*, length 680 feet, breadth 75 feet; the *Walmer Castle*, length 570 feet, breadth 64 feet, and other recent vessels, indicate a decided tendency towards the establishment of a ratio of 9 to 1. The maximum beam does not yet exceed 78 feet, which is amply covered by entrance locks and passages 80 to 100 feet in width, constructed fifty years ago under the régime of paddle steamers. Consequently, the increase in beam has not had so perceptible an effect on dock construction as the increase in length.

Only in depth has the progress of naval construction been less marked. The draught of the *Campania*, 23 feet, in 1893 was no greater than that of some vessels twenty years before. The latest German types have a loaded draught of only 29 feet, while the most modern British vessels attain to 32 feet; but in neither case is the increase proportional to that of the other dimensions. This discrepancy is due to the difficulty of obtaining adequate depth of water in approach channels and over the sills of existing docks. Ever since 1893 naval architects have been calling for deeper entrances. They point out that the length and breadth of vessels cannot be indefinitely increased without some corresponding increment in depth, and that unless this be obtainable, a limit will inevitably be imposed upon the construction of leviathan steamers. The difficulty of meeting this demand lies in the fact that while the widening of entrances, where necessary, is in the majority of cases feasible at a comparatively mod-

erate cost, the deepening of sills can be effected only at considerable outlay. Yet even in this respect much has been achieved of late years, more especially in extension works. Notably the sills of new Liverpool docks are being laid at 10 feet below the level ruling a decade ago, and 20 feet below the level of the sill of the Old Dock, which marked the requirements of ships 200 years back.

The following statistics afford an interesting comparison of the principal dimensions of leading vessels of three different periods. They constitute the average of those of the twenty largest steamships existing at each of the dates named:—

	1881	1891	1901
Length, feet	460	507	599
Breadth, feet	45	54½	65
Depth, feet	30	31	39
Loaded draught, feet	24	27	32
Tonnage	4,900	6,980	14,150

The shape or form of docks has not undergone any material modification since their inception. All geometrical figures are available for dock plans, but curvilinear outlines are unsuitable, and the favourite shape, as indeed the most convenient, is rectangular, either as a simple oblong, or with branches at right angles to a main body, creating a form which may best be described as the tridentime, though the number of the branches is not necessarily confined to three. This, however, is the number generally adopted, and it probably represents the number most consistent with compactness and utility. The Tilbury Docks at London, Fig. 5, opened in 1886, have been constructed on this plan, and other examples of the same kind are to be found in the Alexandra and Huskisson Docks at Liverpool, the Prince's Dock at Glasgow, and the Bassin National at Marseilles. To meet the conditions of road traffic the branches should be to the landward of the main dock.

It should not be overlooked that the plans of docks are rarely under the unrestricted control of the engineer, and that, in most instances, they are governed by considerations of site and economy. The acquisition of land for dock purposes is generally an expensive proceeding, owing to the high market value of eligible situations. Purchases have, accordingly, to be confined within strictly utilitarian limits, and the boundaries of land so acquired are frequently irregular, necessitating considerable skill in laying out the enclosed areas to the best advantage. The complexity of many dock systems and the apparent eccentricity of their outlines are due to such conditions of evolution.

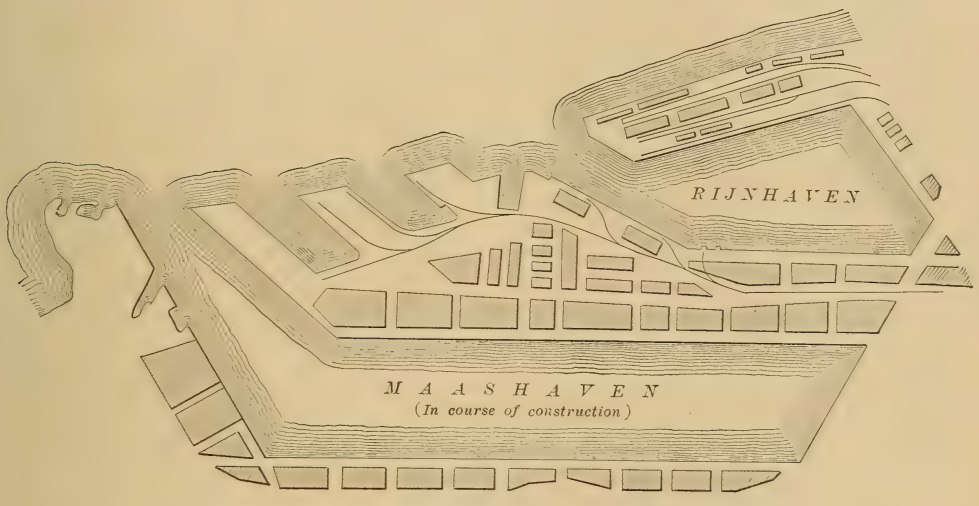


FIG. 8.—THE NEW BASIN AT ROTTERDAM

A unique form is that represented by the Empress Dock, Fig. 6, at Southampton, constructed in 1890. It may appropriately be called the *lozenge*. With the entrance at one of its acute angles, a most convenient and advantageous arrangement is obtained for the docking and undocking of ships.

It is undoubtedly advisable for a ship to leave a dock stem first, and, as she usually makes her entry in this manner, ample space should be provided for turning within the dock, unless indeed it happens that there is width enough in the outer waterway for the manœuvring to take place there. An outer, or tidal, basin is in many cases provided for the purpose, and this serves the additional object of affording convenient cover for vessels from wind and current while manœuvring into a narrow waterway.

In order to keep existing accommodation up to date, some improvement in the efficiency of a group of old docks, the sills of which, under normal conditions, are impracticably high for modern vessels, has been achieved by providing the group with a vestibule basin having entrance gates and a deep sill. The level of the water in the inner system is then artificially raised by pumping, and sufficient draught is afforded in this way for the passage of shipping into the inner docks. The method, however, is generally costly, involving, as it does, a large outlay in pumping plant and considerable working expenditure. It has been adopted in connection with certain docks at the north end of the Liverpool Dock Estate, which are shown in Fig. 7. Thus the water in the Canada-Huskisson docks can be raised to give any additional depth of water required in the Canada dock and its south passage, so that the passage may have the same effective depth as the river entrances to the Sandon half-tide dock, the sill of which is 4½ feet lower.

The group of docks shown in Fig. 7 includes some of the more recent examples of dock work at the port of Liverpool. The Hornby-Alexandra-Langton system, constructed under the direction of the late Mr. G. F. Lyster, was opened in 1881. Within the last ten years various improvements have been effected in the older group of docks, to which reference has already been made, viz., the Canada-Huskisson-Sandon group, by Mr. A. G. Lyster, the present engineer-in-chief to the Mersey Docks and Harbour Board. The system has been practically remodelled, with the addition of three new branch docks and a half-tide basin. The greater part of the water area also has been deepened, necessitating the underpinning of the walls of the docks and the entrance locks to the extent of 12 or 14 feet below their previous levels.

One of the most striking examples of the scope of recent maritime engineering operations is afforded by the transformation, within the last fifteen years, of the inland town of Manchester into a flourishing port, equipped with a complete dock system and all its appurtenances. The docks, which are eight in number, comprise a water area of 104½ acres and a quayage of 5½ miles. Connection with the estuary of the Mersey is effected by means of a canal, 35½ miles in length, affording a navigable depth throughout of 26 feet.

The town of Barry, in South Wales, is another port of modern creation. Twenty years ago it was an insignificant village of barely one hundred inhabitants. At the present time it has a group of docks covering 155 acres of water, with a quayage of 5 miles, and its population has increased to over 30,000. The docks are almost exclusively devoted to the coal and timber trades.

Still another instance of activity in dock construction is furnished by recent enterprise at the port of Glasgow. Of its three existing docks, two are of quite recent origin, and a fourth is in process of formation. On the north side of the Clyde the Queen's Dock, comprising an area of nearly 34 acres, was completed in 1880, and on the south side of the river the Prince's Dock, of very slightly larger area, was brought into use in 1897. Present operations are being conducted at Clydebank, where a dock of 17 acres is in hand. The Clyde, though a tidal river, is not characterised by excessive fluctuations in level, and

accordingly the docks at Glasgow are without gates.

Fig. 8 is the plan of a very large dock, or tidal basin, now in course of construction at the port of Rotterdam. It has an area of about 145 acres. As the extreme range of tide is only about 6 feet, the basin is in free communication with the outer waterway. The entrance is 460 feet wide, and there is a draught of nearly 28 feet at low water, increasing generally to 31 feet at high water. The basin has been in partial use for sea-going vessels since March last.

Docks or basins of so large a size are rare. The majority comprise less than 50 acres, and some of the older docks are very small. The size, of course, is now increasing. The No. 1 dock at Barry is 73 acres in extent,—a trifle larger than either the Victoria or Albert docks at London. The Bassin National at Marseilles has an area of 102 acres; the Segelschiffhafen and the Hansahafen at Hamburg have areas of 86 and 90 acres, respectively, and there is a dock at Dunkirk, the Bassin de Freycinet, which, with its branches, comprises 105 acres. These represent the largest of modern docks.

POWER STATION AT THE END OF A CANAL A QUARTER OF A MILE LONG, TAKING WATER FROM THE CHICOPEE

THE LOCATION OF ELECTRIC WATER-POWER STATIONS

SOME EXAMPLES FROM AMERICAN PRACTICE

By Alton D. Adams

COST of water-power development depends, in large measure, on the location of the electric station that is to be operated. The form of such a station, its cost, and the type of generating apparatus to be employed are also much influenced by the site selected for it. This site may be exactly at, or far removed from, the point where water that is to pass through the wheels is diverted from its natural course.

A unique example of a location of the former kind is to be found near Burlington, Vt., where the electric station is itself a dam, being built entirely across the natural bed of one arm of the Winooski River at a point where an island near its centre divides the stream into two parts. The river at this point has cut its way down through solid rock, leaving perpendicular walls on either side. Up from the ledge that forms the bed of the stream, and into the rocky walls, the power station, about 110 feet long, is built. The up-stream wall of this station is built after the fashion of a dam, and is reinforced by the down-stream wall, and the water flows directly through the power station by way of the

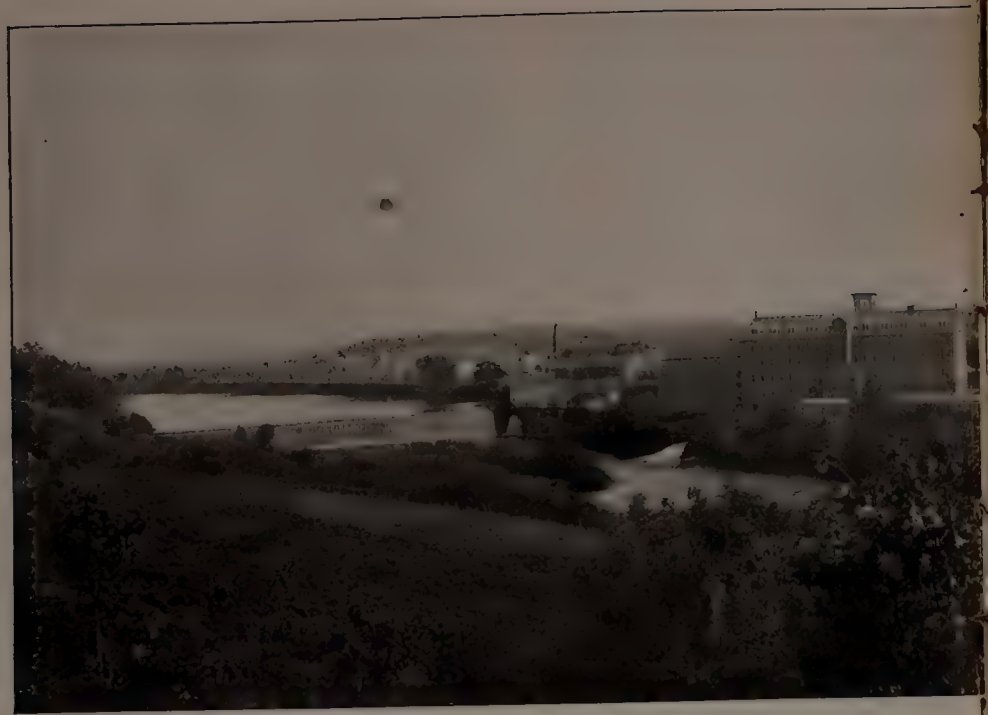
RIVER NEAR SPRINGFIELD, MASS., WHERE THE FALL IS 36 FEET. THE POWER HOUSE IS AT THE EXTREME RIGHT

wheels. A construction of this sort is all that could well be attained in the way of economy, there being neither canal nor long penstocks, and only one wall of a power house apart from the dam. On the other hand, the location of a station directly across the bed of a river in this way makes it impossible to protect the machinery if the up-stream wall, which acts as the dam, should ever give way. The peculiar natural conditions favourable to the construction just considered are seldom found.

One of the most common locations for an electric water-power station is at one side of a river, directly in front of one end of the dam and close to the foot of the falls. A location of this kind was adopted for the station at Gregg's Falls, one of the water-powers included in the electric system of Manchester, N. H., where the spray of the fall rises over the roof of the station. Two short steel penstocks, each 10 feet in diameter, convey the water from the forebay section of the dam to wheels in the station with a head of 51 feet.

A similar location was selected for the station at Great Falls, on the Presumpscot River, whence electrical energy is delivered in Portland, Me. Four steel penstocks, a few feet long and each 8 feet in diameter, bring the water in this case from the forebay section of the dam to the wheel cases in the power house.

Where the power station is located at the foot of the dam, as just described, that part which serves as a forebay wall usually carries a head gate for each penstock. The overfall section of a dam may give way in cases like the two just noted without necessarily destroying the power station, but in times of freshet or very high water the station may be flooded and its operation stopped. The risk of any such flooding will vary



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THIS POWER HOUSE, ON THE WINOOSKI RIVER, NEAR BURLINGTON, VERMONT, SERVES THE DOUBLE FUNCTION OF POWER HOUSE AND DAM, BEING BUILT IN A ROCKY GORGE, AS SHOWN

greatly on different rivers, and in particular cases may be very slight. Location of the generating station close to the foot of the dam at one end obviously avoids all expense for a canal and cuts the cost of penstocks down to a very low figure.

Such locations for stations are not limited to falls of any particular height, and the short penstocks usually enter the dam nearer its base than its top and pass to the station at only a slight inclination from the horizontal. At Great Falls, above mentioned, the head of water is 37 feet.

A short canal is constructed in some cases from one end of a dam to a little distance down stream, terminating at a favourable site for the electric station. Construction of this sort was adopted at the Birchem Bend Falls of the Chicopee River, whence energy is supplied to Springfield, Mass. These falls furnish a head of 14 feet, and the water-wheels are located on the floor of the open canal at its end. The power station is on the shore side of this canal, and the shafts of the water-wheels extend through bushings in the canal wall, which forms the lower part of one side of the station, to connect with the electric generators inside.

This rather unusual location of water-wheels has at least the obvious advantage that they require no room inside of the station. Furthermore, as the canal is between the station and the river, any break in the canal is not apt to flood the station.

An illustration of the use of a very short canal to convey water from one end of a dam to a power station exists in the 10,000 horse-power plant at Cañon Ferry, Montana, where the head of water is 30 feet. In this case the masonry canal is hardly larger than the power house, and this latter sits squarely between the canal and the river, virtually at the foot of the falls. Other examples of the location of generating stations between short canals and the river may be seen at Concord, N. H., where

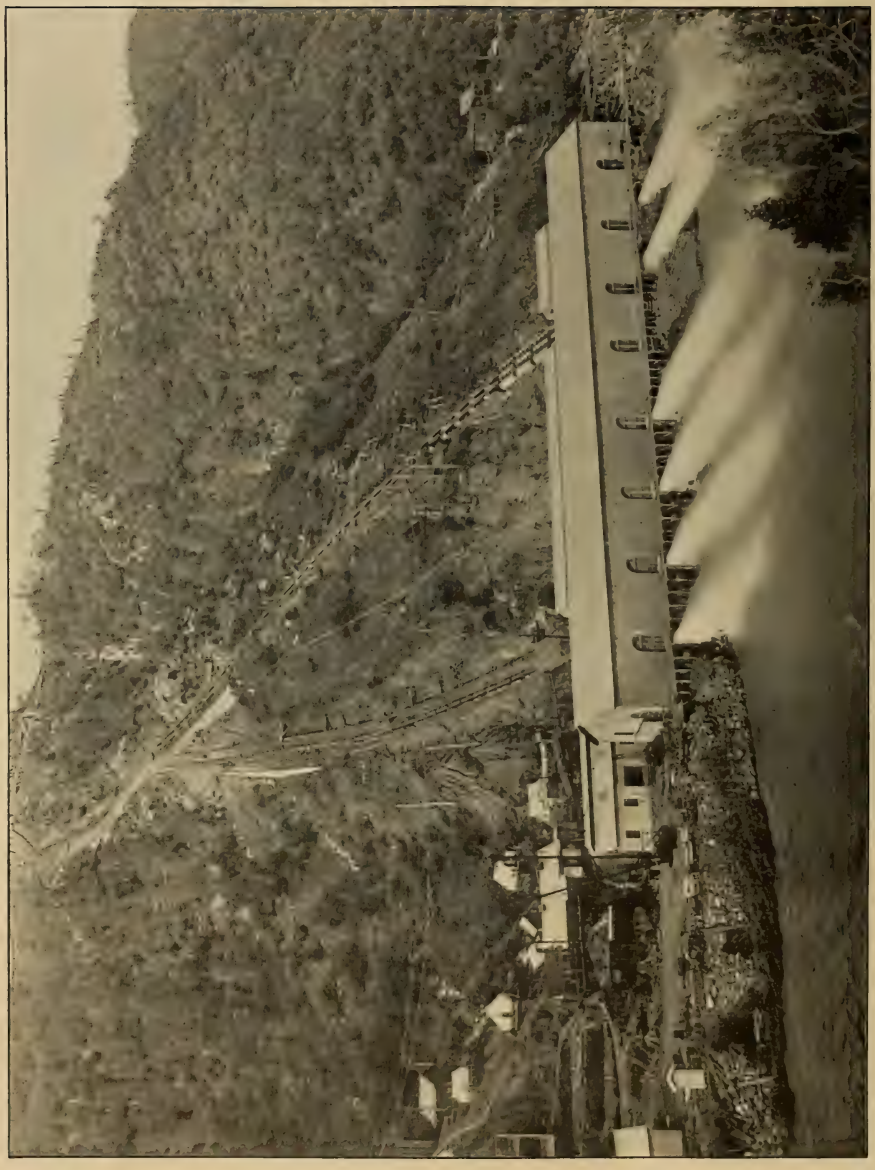
the head of water is 16 feet; at Lewiston, Me., where the head is 32 feet; and at Spier's Falls, on the Hudson River, New York, where there is a head of 80 feet.

There is some gain in security in many cases by locating the power station several hundred feet from the dam and a little to one side of the main river channel. For such cases a canal may be cheaper than steel penstocks when the items of depreciation and repairs are taken into account. Aside from the question of greater security for the station in the event of a break in the dam, it is necessary in many cases to convey the water a large fraction of a mile, or even a number of miles, from the point where it leaves its natural course to that where the power station should be located. An example in point exists at Springfield, Mass., where one of the electric water-power stations is located about 1400 feet down stream from a fall of 36 feet in the Chicopee River, because land close to the falls was all occupied at the time the electric station was built. This is illustrated on pages 496 and 497.

The Shawinigan Falls of the St. Maurice River in Canada occur at two points a short distance apart, the fall at one point being about 50 and at the other 100 feet high. A canal, 1000 feet long, takes water from the river above the upper of these falls and delivers it near to the electric power house on the river bank below the lower falls. In this way a head of 125 feet is obtained at the power house. The canal in this case ends on high ground 130 feet from the power house, and the water passes down to the wheels through steel penstocks 9 feet in diameter.

THE GREAT FALLS POWER HOUSE OF THE PORTLAND LIGHTING AND POWER COMPANY ON THE PRESUMPSCOT RIVER, NEAR PORTLAND, MAINE, IS LOCATED DIRECTLY IN FRONT OF ONE END OF THE DAM CLOSE TO THE FALLS

Another interesting example of conditions that require a power house to be located some distance from the point where water is diverted from its natural course may be seen at the falls on the Apple River, whence energy is transmitted to St. Paul, Minn. By means



THE POWER HOUSE AT COLGATE, CALIFORNIA, OF THE BAY COUNTIES POWER COMPANY. THE WATER COMES FROM THE NORTH YUBA RIVER THROUGH NEARLY 8 MILES OF WOODEN FLUME TO THE HILL TOP 700 FEET ABOVE THE POWER HOUSE

of a natural fall of 30 feet, a dam 47 feet high some distance up stream, and some rapids in the river, it was there possible to obtain a total fall of 82 feet. To utilise this entire fall a timber flume, 1550 feet in length, was built from the dam to a point near the power house on the river bank and below the falls and rapids. The flume was connected with the wheels, 82 feet below, by a steel penstock, 313 feet long and 12 feet in diameter.

As the St. Mary's River leaves Lake Superior, it passes over a series of rapids about half a mile in length, falling 20 feet in that distance. To make the power of this great volume of water available, a canal, 13,000 feet long, was excavated from the lake to a point on the river bank below the rapids. Between the end of the canal and the river sits the power station, acting as a dam, and the water passes down through it and the wheels under a head of 20 feet.

By means of a canal 16,200 feet long a head of water amounting to 50 feet has been made available at a point on the bank of Grass River near Massena, New York. There again the power station acts as a dam, and the canal water passes down through it to reach the river.

From these illustrations it may be seen that in many cases, in comparatively level country, a water power can be fully developed only by means of canals or pipe lines, and the generating stations cannot be located at the points where the water is diverted.

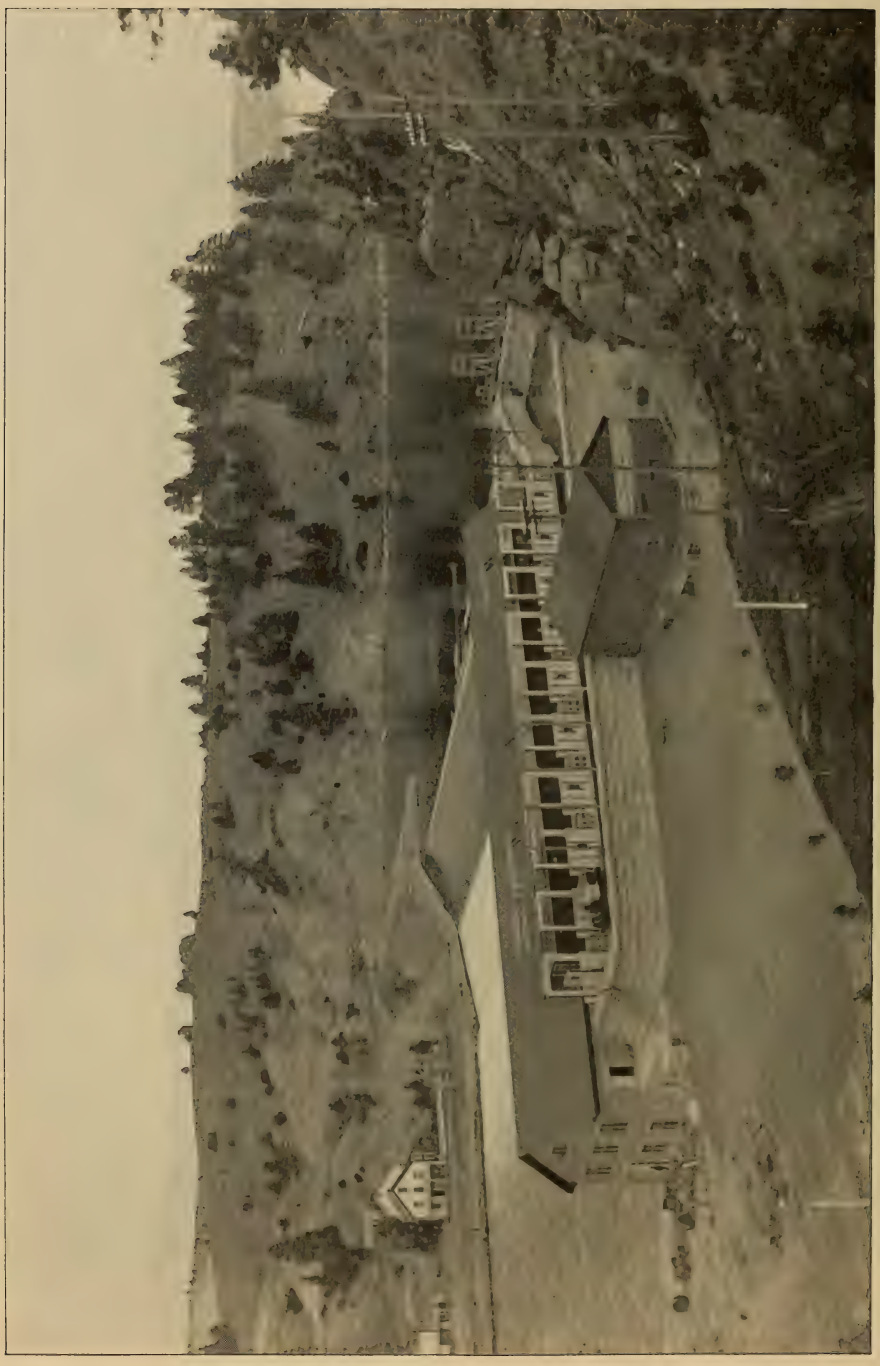
Thus far the cases considered have been only those with moderate heads and rather large volumes of water. In mountainous country, where rivers are comparatively small and their courses are marked by numerous falls and rapids, it is generally necessary to utilise the fall of a stream through some mile of its length in order to effect a satisfactory development of power. To reach this result, rather long canals, flumes, or pipe lines must be utilised to convey the water to power stations and deliver it at high pressures.

In cases of this kind the cost of the canal or pipe line may be the largest item in the power development, and it may be an important question whether this cost should be reduced or avoided by the erection of several small generating plants instead of one large one. California offers numerous examples of electric power development with water that has been carried several miles through artificial channels. An illustration of this class of work exists at the Electra power house on the bank of the Mokelumne River, in the Sierra Nevada Mountains. Water is supplied to the wheels in this station under a head of 1450 feet through pipes 3600 feet long leading to the top of a nearby hill. To reach this hill the water, after its diversion from the Mokelumne River at the dam, flows twenty miles through a canal or ditch and then through 3000 feet of wooden stave pipe.

Another example of the same sort may be seen in the power house at Colgate, on the North Yuba River, in the chain of mountains above named. Water taken from this river passes along a wooden flume nearly eight miles long to the side of a hill 700 feet above the power house, and thence down to the wheels through steel and cast iron pipes, five in number and 30 inches each in diameter.

Even with long flumes, canals, and pipe lines it is necessary to locate a number of generating stations along a single river of the class now under consideration in order to utilise its entire power. Thus on the Kern River, which rises in the Sierra Nevada Mountains and empties into Tulare Lake, two electric power stations have been under construction, and surveys are being made for three more. Of these stations the one at the lowest level will operate under an 872-foot head of water, and this water, after its diversion from the river, will pass through twenty-one tunnels, with an aggregate length of about ten miles, and through six flumes mounted on trestles and having a total length of 1703 feet.

Next upstream is a station near the point where water is diverted for the plant just named. This second station will work under a head of 317 feet, and



THE MISSOURI RIVER POWER COMPANY'S 10,000 H. P. GENERATING STATION AT CAÑON FERRY, MONTANA. A GOOD ILLUSTRATION OF THE USE OF A VERY SHORT CANAL FROM DAM TO POWER HOUSE

water for it will come from a point further upstream by canals, tunnels, and flumes, with an aggregate length of eleven and one-half miles. At three points still higher up on this river it is the intention to locate three other power stations by conducting the water in artificial channels, about twelve and one-half, fifteen, and twenty miles in length, respectively.

Further south in California, on the Santa Ana River and Mill Creek, extensive power developments on the lines just indicated have been carried out. On Mill Creek, about six miles from the city of Redlands, is an electric station operating under a head of 530 feet, with water in part diverted from the stream a little less than two miles above and brought down through a steel pipe 10,250 feet long and 30 inches in diameter. This pipe line also takes water from the tail race of another generating plant at its upper end. With some additions and modifications, the station just described is the famous Redlands plant, built in 1893, and believed to be the first for electric three-phase working in the United States.

At the upper end of the pipe-line just named the second station operates, in part, with water drawn from Mill Creek through a combination of tunnels, flumes, and cement and steel pipes, with a combined length of about three miles, and delivered to some of the wheels with a head of 627 feet. The other wheels at this plant receive water drawn from the same creek by a pipe-line about six miles long. A large part of this line is composed of 31-inch cement pipe, laid in trenches and tunnels. The water in the 8000 feet of pipe next to the power house has a fall of 1960 feet, and this pipe is of steel and 24 and 26 inches in diameter. The head of 1960 feet, minus friction losses in the steel pipes, is delivered at the wheels, and is probably the greatest at which an electric station operates anywhere.

From the foregoing it appears that in a space of eight miles along Mill Creek there is a fall of more than 2490 feet, since the cement pipe lines and flumes must use up quite a large pressure. To utilise this fall water is diverted from the creek at three points within a distance of six miles and delivered in two power stations under three different heads. As the stream gathers in volume between the upper and the lower intakes, an equal amount of power could have been developed in a single station only by taking the three separate conduits or pipe lines to it and delivering their water there at three heads.

Whether the expense of extending conduits and pipe lines to a single generating station will more than offset the advantages to be gained thereby is a question that should be decided on a number of factors varying with each case. In general, it may be said that the smaller the volume of water to be handled and the greater its head, the more advantageous is it to concentrate the generating machinery in the smallest practicable number of stations.

On the Santa Ana River, into which Mill Creek flows, the famous Santa Ana plant, whence energy is transmitted to Los Angeles, is located. Water reaches this plant through a conduit of tunnels, flumes, and pipes, with a total length of about three miles from the point where the flow of the river is diverted. The 2210 feet of this conduit nearest the power plant are composed of 30-inch steel pipe, with a fall of 728 feet.

Within fifteen miles of Mexico City are five water-power stations that supply energy for its electrical system. Two of these stations are on the Monte Alto and three are on the Tlaluepantla River, the two former stations being about three miles, and the more distant of the three latter stations five miles, apart. At a distance of several miles above the highest station on each river the water is diverted by a canal, and the water of each of these canals, after passing through the wheels of the highest station, goes on to the remaining station, or stations, on the same river by a continuation of the canal.

By placing the stations so short a distance apart the construction of canals and pipe-lines is made less expensive than it would be with only one larger station on each river, and the head of

water at each station is reduced. On one stream these heads are 492 and 594 feet, respectively, and at two of the stations on the other stream they are 547 and 295 feet, respectively. This division of the total head of water afforded by each river results in a rather small capacity for each station, the total at the five plants being only 4225 kilowatts.

In contrast with this figure, the already-mentioned Electra plant has generators of 10,000, the Santa Ana plant generators of 3000, and the larger of the two Mill Creek plants, generators of 3500 kilowatts capacity. It should be noted that the cost of operation, as well as that of original construction, will vary materially between one large and several smaller stations of equal total capacity, the advantage as to operative cost being obviously with the one large plant.

All of the power stations here considered have been equipped with water-wheels and generators operating on horizontal shafts, and this is the general practice. This arrangement brings the generators and the floor of the power station within a few feet of the level of the tail water. By the general use of draught tubes where the heads of water are less than 200 feet the floors of stations are kept something less than 20 feet above the tail-water level.

Where the total available head of water is quite small, as is often the case with rivers where the volume of water is great, it is generally necessary to bring the level of the station floor down to within a very few feet of the tail water. The Birchem Bend station of the Springfield, Mass., electric system affords a good example of this sort, the floor of this station being only 2.6 feet above the ordinary level of the tail water. At this station the difference of level between the head and tail water is only 14 feet, and even with the low floor level named the top sides of the horizontal turbine wheels are covered by only 4.5 feet of water.

At the Garvin's Falls station of the Manchester, N. H., electric system the level of the floor of the generator room is 13 feet above the ordinary level of the Merrimac River, on the bank of which this station is located; but in this case the total head of water is about 28 feet. The high water of the Merrimac in 1896, before the Garvin's Falls station was built, reached a point 5.24 feet above its present floor level, and 18.24 feet above the ordinary level of the river at the point where the station is located.

Under the Red Bridge electric station of the Ludlow Manufacturing Company, on the Chicopee River, in Massachusetts, the tail water is 20 feet below the level of the floor and 24 feet below the centres of the water-wheel and generator shafts. The difference between wheel shaft and tail-water levels at this station is near the maximum that can be attained with horizontal pressure turbines, because a draught tube much longer than 20 feet does not give good results.

In a pressure turbine the guides and wheel must be completely filled with water, as must also the draught tube, for efficient operation. If draught tubes are much more than 20 feet long, it is hard to keep a solid column of water from turbine to tail water in each, and if this is not done, a part of the head of water becomes ineffective. As pressure turbines are employed almost exclusively at electric stations with low heads of water, it is frequently impossible to locate such stations above the possible level of tail water in times of flood if horizontal wheels direct-connected to generators are employed.

If turbines with vertical shafts are to be used, a power station may be so located or constructed that all the electrical equipment will be above the highest known water mark. With vertical shafts, connecting wheels and generators, the main floor of an electric station may be located above the crest of the falls where the power is developed instead of at or near their base.

By far the most important example of electric stations laid out on this plan is that at Niagara Falls, where the two generating plants, with an aggregate capacity of 105,000 horse-power, stand a short distance above the falls, and are supplied with water through a short canal from Niagara River. Beneath

each station a long, narrow wheel pit has been excavated through rock to a depth of 172 feet below the level of water in the canal. Both wheel pits terminate in a tunnel 7000 feet long that opens into the river below the falls.

In this wheel pit the tail-water level is 161 feet below that of the water in the canal, and 166 feet below the floor of the power station. Water passes from the canal down the wheel pits to the wheels near the bottom through steel penstocks, each 7 feet in diameter, and a vertical shaft extends from each wheel case to a generator in the station above.

Locations like that at Niagara give great security against high water and washouts, but are seldom adopted because of the large first cost of plant construction. With heads of water from several hundred to 2000 feet the loss of a few feet of head reduces the available power to only a very slight extent, and impulse wheels are usually employed. Draught tubes are not available to increase the heads at such wheels, and any fall of the water after it leaves the wheels does no useful work.

Electric stations driven by impulse wheels under great heads, like those at Colgate, Electra, Kern River, Santa Ana River, and Mill Creek, may be located far enough above the beds of their water courses to avoid dangers from freshets, without serious loss of available power.

SOFTENING AND PURIFYING WATER FOR BOILERS

By J. C. W. Greth

From the steam raiser's point of view Mr. J. C. W. Greth's paper on "The Softening and Purification of Water," recently read before the Engineers' Society of Western Pennsylvania, is one of the best contributions latterly made to the literature of the subject; hence its republication here practically in full. The apparatus itself for softening water is described in only a general way; but the need and benefits of what it accomplishes are presented at length and in a manner that appeals forcibly to the business man. —THE EDITOR.

THE impurities in water are of two kinds,—viz., organic and inorganic,—and may be either in suspension or in solution. Those in suspension have received the most attention from engineers and deal with the sanitary purification of water for use in cities, public buildings, etc. It presents, however, an entirely different problem from the softening and purification of water for boiler feed and manufacturing purposes, and the work is usually performed by sand filter beds or mechanical filters. The presence of organic matter or bacteria, either in solution or suspension, which would be detrimental to public health, would not have any injurious effect on a boiler. The inorganic matter, such as soluble lime, magnesia and iron, as well as free acids and silt or clay, does cause an unnecessary amount of labour and expense.

THE IMPURITIES IN WATER

The usual inorganic substances in water are the following, and are grouped as to the trouble they usually cause in steam boilers:—Carbonates and sulphates of lime and magnesia, silica, oxides of iron and alumina and suspended matter. All of them tend to form scale.

The following cause corrosion:—Sulphuric, hydrochloric, carbonic, acetic, and tannic acid. The latter two are usually due to contamination from chemical works or other processes in which these acids are either used or developed.

Iron sulphate and magnesium chloride belong in a class by themselves, as they not only form scale, but are corroding agents besides.

The carbonates, sulphates and chlorides of sodium and sometimes potassium are found, especially sodium chloride. These substances cause no particular harm, except when they are present beyond a certain amount, in which case foaming will result.

When a water which contains a part or all of these impurities is heated to 212 degrees F., and is boiled for some time, the carbonates of lime and magnesia are precipitated; but it requires a temperature of about 300 degrees F. (or steam at 70 pounds pressure) to precipitate the sulphates of lime and magnesia. The continual evaporation of the water concentrates these impurities until finally the point of saturation is reached. Then the bulk of the more soluble impurities is precipitated, together with the less soluble carbonates, sulphates and even chlorides. This deposit of scale forms wherever the water comes in contact with the hot metal. The deposit is piled up in thin layers of iron, silica, lime and magnesia, and is generally the thickest where the least amount of steam is generated. The consequences are generally serious. The carbonates of lime and magnesia are non-conductors of heat, having relative values of 0.67 and 0.76 (felt or wool being 1.00). It is claimed that the conducting power of iron for heat is about thirty times that of saturated scale.

THE EFFECT OF SCALE

The effect of covering the metal with this non-conducting material is:—

1.—The increased amount of fuel which it is necessary to use in order to

raise the temperature of the water to a given point or to generate steam.

2.—There is great danger of burning or overheating the boiler, by reason of the fact that the water is not in immediate contact with the shell and cannot carry off or absorb the heat from the plates. The boiler being under pressure, the overheating of the metal results in the stretching of the plate, forming a bag; or the metal may blister or crystallise, which will very much reduce its tensile strength, rendering the boiler unsafe. This means that repairs are in order, even in cases where the metal does not get heated enough to bag or blister, but is sufficient to cause the metal to expand unequally, distorting it and the joints between the several parts of the boiler. This causes leaks, which, in time, become serious enough to put the boiler out of use. Even under conditions where no disastrous results follow, a great deal of labour on the part of the engineer in charge is necessary to keep the scale from accumulating. Continual hammering and chipping are injurious to the metal, and even if the intentions of the cleaner are the best, it is impossible to reach all parts of the modern steam generator for cleaning.

The boilers are not the only part of the steam generating plant which are affected by the impurities of the water. A deposit of a part of the carbonates of lime, magnesia and iron takes place when the water reaches the exhaust steam heater. The same trouble arises in steam plants using economisers or heaters through which the water passes after it leaves the exhaust steam heater, and before it reaches the boilers. These obtain their heat from the waste gases of the furnace, and it is very important that their surfaces should be clean and be kept so without involving a great deal of labour and expense. A deposit, too, especially from well waters, takes place in the feed pipes, valves, pumps, etc.

THE ACTION OF ACIDS

The action of the acids is a subject which interests us considerably on account of the surrounding rivers containing more or less, either in the free state or loosely combined.

The action is, briefly, as follows:—Sulphuric acid, the one most common, is either in a free state or combined with iron as the sulphate, which the heat immediately splits up into iron oxide and sulphuric acid. In the boiler, the acid attacks the metal of the boiler, forming iron sulphate, which immediately splits up into sulphuric acid and an iron salt, which, through various stages, eventually reaches the shape of ferric oxide, which is precipitated. The acid being set free, this, with more acid coming in with the water, again attacks the iron and goes through the same process again, and eventually a water which might contain only three or four grains of free acid on entering a boiler may become a strong solution and carries on its work of rapid disintegration of the iron of the boiler. These are substances the removal or neutralisation of which form the subject of this paper.

MECHANICAL DEVICES FOR PURIFICATION

Let us first consider some of the mechanical devices and methods employed, with more or less success, in the purification of water for boiler feed purposes. The carbonates of lime, magnesia and iron are soluble in waters having carbonic acid in solution. When this water is heated to a temperature of 212 degrees F. and boiled for a time the carbonic acid is driven off and the carbonates are precipitated. This fact is made use of in the ordinary exhaust steam heater, and is the reason for its being called a water purifier. These heaters are not built of sufficient size, nor is the temperature of the water really ever raised to the boiling point, nor is the water kept in the heater or at this temperature long enough to drive off all the free or loosely combined carbonic acid, or, in other words, bring about the precipitation of all the carbonates in the heater. A portion of them are removed. The following analysis, before and after going through an exhaust steam heater

of a well-known make, shows the extent of the removal of the carbonates:—

		Grains per U. S. Gallon Before	After
Carbonates.	Calcium	8.3194	5.0632
	Magnesium	3.6087	1.2243
Sulphates—Calcium		2.8567	2 8521
Chlorides	Magnesium	1.4225	1.4181
	Sodium	1.6149	1.6142
Oxides	Iron and alumina	0.2915	0.1666
	Silica	0.8745	0.4897
Volatile and organic matter		1.9996	1.2346
Carbonic acid in solution		5 83	3.071

The sulphates of lime and magnesia are not affected in the exhaust steam heater, as they require a higher temperature to cause precipitation. About 300 degrees F., or steam at 70 pounds pressure, will bring about a precipitation. To find a remedy, or to prevent the precipitation of the sulphates in the boilers, a second tank, like a boiler filled with pans or shelves, and heated with live steam, is brought into use. Into this receptacle all the water passes before it finally reaches the boiler. By maintaining this heater at the boiler pressure the water becomes hot enough to start precipitation of its solids. This is not an instantaneous process, but a gradual one, and it continues after the water has reached the boiler.

Of course, the efficiency of mechanical purifiers depending on heat is pro portional to the length of time during which the water is subjected to the heating process. In practice, the water is never thoroughly purified in exhaust or live steam purifiers, because the heater is usually so small that the water passes through it in too short a time to complete the precipitating process. Sulphate of lime is said to be insoluble at temperatures above 300 degrees. This is true, provided there is a certain amount of it in the water. Analyses of the water from the blow-off valves of boilers show that the sulphate of lime in solution is as high as 25 grains per gallon, even when the temperature is far above 300 degrees. From this it is evident that it is due to concentration as well as to heat that the sulphate of lime precipitates in the boilers, forming scale. Concentration does not take place either in exhaust or live steam heaters, and even if exhaust and live steam heaters did accomplish all that is claimed for them by their makers, they are merely devices for the prevention of scale in the boilers by forming the scale in the heaters themselves, which means that, in place of cleaning simply the boilers, both heaters and boilers have to be cleaned. Neither type of heater is of value for the removal of any of the free acids, such as sulphuric, or of such substances as magnesium chloride.

Innumerable other mechanical devices have been tried to overcome this trouble, such as skimmers, surface blow-off valves, etc. Notwithstanding all these contrivances, the scale continued to form on the plates and the tubes of the boilers. Another method is to supply to the heated water in the boiler a remedy which would keep the scale from hardening.

BOILER COMPOUNDS

We now come to the subject of boiler compounds. Mixtures known as boiler compounds have been used for years. The chemistry of boiler compounds is correct, and the subject is thoroughly understood. They are generally composed of soda in combination with some organic acid, such as tannic or acetic acid. All of these acids are said to corrode the metal and to be positively injurious to the boiler.

Almost everything, at one time or another, has been put into the boiler to keep the scale soft, such as shavings, oak bark and tea, for the tannic acid they contain; distillery slops and vinegar, on account of the acetic acid; potatoes and corn, for their starch; leather, slippery elm and manure, for their gelatinous matter, and molasses and sugar, because of the saccharates of lime formed. Innumerable other substances have been used without judgment or reason.

From the chemical standpoint, the most efficient compounds are tri-sodium phosphate and fluoride of sodium. With these, when the water is heated, both the carbonates and sulphates of lime and magnesia are precipitated as phosphates or fluorides, which do not harden on the tubes and shell. The principal objection, however, is the cost of using them

in quantities sufficient to remove enough of the scale-forming matter to be of benefit. They are expensive, first, because the chemical equivalent of these compounds makes it necessary to use 1 pound of tri-sodium phosphate to precipitate 0.9 pound of carbonate of lime or 0.77 of carbonate of magnesia. One pound of fluoride of sodium is required to precipitate 1.19 pounds of lime carbonates or 1.6 pounds of lime sulphates, and its cost at the present writing is about two and a half times that of tri-sodium phosphate. There is, however, not the same degree of economy obtained by the introduction of any foreign substances into the boiler which can be obtained by the use of feed water purified before entering the boilers, because coal, and, therefore, heat, are required to keep the temperature of this muddy, insoluble mass of combined mud and scale to the temperature of the water. Furthermore, this foreign matter absorbs an astonishing amount of heat. It is for this reason that sea water boils at a higher temperature than fresh water, and molasses at a higher temperature than either.

A remedy, to be of benefit, must be applied in the proper manner, at a seasonable time, and at the right place. Simply because a substance will, when put into hard water, precipitate lime and magnesia is no reason why this substance should be put into a boiler. Quite the contrary. Heat, without chemicals, causes precipitation in a boiler, and that is just the thing which is not desired. A steam boiler is a still of high efficiency and not a chemical retort.

The methods described above for the purification of water, either before entering or while in the boilers, have proved unsatisfactory and expensive, and are at best only partially successful.

WATER SOFTENING AND PURIFICATION

We now come to the question of water softening and purification before entering the heaters, economisers or boilers.

The chemistry of the subject is extremely simple. We will first consider the substances available for this purpose, their efficiency and economy. The following table gives the quantities of the various substances required to precipitate 1 pound of carbonate of lime and 1 pound of sulphate of lime, and the cost of so doing. These figures are based on the present market price of the chemicals.

	Cents
0.56 pound lime, at ¼ cent per pound	0.14
2.18 pounds tri-sodium phosphate, at 4 cents per pound	8.72
0.8 pound caustic soda, at 3 cents per pound	2.4
3.15 pounds barium hydrate, at 3 cents per pound	9.45
11.92 pounds tannin extract, 27 per cent., at 2¾ cents per pound	32.78
2.28 pounds sugar, at 5 cents per pound	11.40

For the removal of the sulphates and chloride, 1 pound of sulphate of lime requires for its precipitation:—

	Cents
0.85 pound soda ash, at 1 cent per pound	0.85
1.53 pounds barium chloride, at 2 cents per pound	3.06
8.76 pounds tannin extract, 27 per cent., at 2¾ cents per pound	24.09
1.68 pounds sugar, at 5 cents per pound	8.40
1.6 pounds tri-sodium phosphate, at 4 cents per pound	6.40

An examination of the tables shows conclusively that lime and soda ash are the most efficient and decidedly the cheapest chemicals that can be used for this purpose.

On account of their low cost, the small amount required, as compared with other chemicals, and the fact that after the chemical reaction has taken place no deleterious substances are left in solution, lime and soda are the ideal substances for use for the purification of all ordinary water supplies so as to render them fit for boiler use and to prevent the accumulation of scale in heaters and boilers.

SODA ASH AND LIME

If it is desired to remove the lime, magnesia or iron from the water, the first step is to find a way to convert them into an insoluble condition. These mineral impurities are held in solution by the acids combined with them, such as carbonic, sulphuric and hydrochloric. Carbonates of lime, magnesia and iron can be made insoluble by removing from the water the free or loosely combined carbonic acid, by means of caustic lime (Clarke process), and the sulphates and chlorides of lime and magnesia by the

use of carbonate of soda (soda ash), because the sulphuric acid or hydrochloric acid has a stronger affinity for soda than for the weaker bases. By the addition, therefore, of these two reagents, in the proper proportions, to the hard water a chemical reaction takes place, followed by the precipitation of the lime, magnesia and iron. In a properly constructed apparatus these impurities can be removed from the water and at the same time the mud and bacteria are mechanically removed and the organic matter materially reduced. When waters contain only a small amount of free acid the treatment used is the lime and soda ash, the same as in other cases; but when the waters run high in sulphuric acid (as, for instance, the Yough River or mine waters) another treatment is employed. Witherite is used for the removal of the acid and whatever sulphates will combine with it are precipitated. The disadvantage, however, in using this substance is that it is insoluble, and this makes its use, in anything but an intermittent system, practically impossible. The softening and purification of water is an exact process, because an exact amount of chemicals is used to remove a known quantity of impurities, previously determined by chemical analysis. Therefore, the cost varies with the quantity and character of the impurities which the water contains.

It might be interesting, at this point, to give some idea of foreign matter brought by a water into a steam boiler, and to one who has never figured this out the amount is astonishing. For instance, in a 500 horse-power plant evaporating 30 pounds of water per horse-power, or 15,000 pounds per hour, equal to about 18,000 gallons per day, it amounts to 3,285 tons in 365 days, when the water contains 7 grains per U. S. gallon, and 13.14 tons for water with 28 grains.

There is some objection to the use of soda ash directly in the boilers, because it has a tendency to make the water foam; but there is a great difference between using soda ash in a softening plant and using it directly in the boilers. In a properly designed water purifying plant the carbonic acid is all absorbed first, and the soda ash does not go into the boilers as a carbonate or bicarbonate, but always as a sulphate or chloride, having decomposed the sulphate or chloride of lime and magnesia. Under certain conditions the same results take place in boilers. For instance, if a raw water contains no carbonic acid, or carbonates, and if the soda ash is used directly in the boiler, a decomposition takes place at once and the soda unites with the sulphuric and hydrochloric acid, and the carbonic acid of the sodium carbonate unites with the calcium and magnesium, precipitating them as sludge. No foaming due to sodium carbonate takes place under these conditions. But if raw feed water does contain carbonic acid or carbonates, and the sodium carbonate is used directly in the boilers, then it first absorbs the free carbonic acid, which holds the carbonates in solution, and becomes a bicarbonate of soda. Heat drives this extra carbonic acid off, and it is this decomposition of bicarbonate of soda which is one of the causes of foaming. This is aggravated if there is any grease or oil carried over from the feed water heaters to the boilers.

The concentration of sodium salts, other than carbonates, will foam; but there is no good reason why there should be a concentrated solution when there is a good blow-off cock on the boilers and an intelligent engineer to use it. There are other causes of foaming, such as organic matter, when surface water is used for feeding boilers.

Sodium and potassium cannot be extracted from water by chemical means, although it is sometimes claimed by eager salesmen that all potassium and sodium salts can be removed or precipitated from a raw water by their apparatus or by the chemical reagents used by them. It is absolutely impossible to remove from water, by sedimentation or filtration, any impurities, unless they can first be converted into a state of suspension, either by heat or chemical treatment. All sodium and potassium salts, whether sulphate, chloride, nitrate, carbonate, phosphate or fluoride,

etc., are soluble in water under the temperatures in steam boilers. None of these can be precipitated either by heat or chemical treatment, and, therefore, none can be removed in any type of water softening and purifying apparatus. There is but one method, and that is distillation; but that is what a steam boiler does when it makes steam. It is true that alkaline salts can be decomposed by chemical treatment, but no benefit is derived, as the alkaline base merely changes its acid radical to a new salt, which is still soluble in water.

The process of softening and purifying water is based upon the exact quantity and chemical character of the impurities in the water. It is a method based upon an accurate chemical knowledge, and does not require the imagination of any man to prove its efficiency.

The Porter-Clarke process of precipitating carbonates of lime and magnesia by means of caustic lime, and the sulphates and chlorides of lime and magnesia by the soda ash treatment, makes it possible to get a clear feed water low enough in scale-forming substances to fulfill all requirements. True water softening is an exact process. By this is meant that the exact amount of lime must be put into the water to remove all the carbonates of lime and magnesia present, and the exact amount of soda ash to decompose all the sulphates and chlorides of lime and magnesia, no more and no less. If it is desired to run at the lowest cost of operation, the apparatus must be so simple that any man who has no knowledge of chemistry can operate it, and of whom nothing but the mechanical work is required.

THE CONTINUOUS SYSTEM

The apparatus designed to accomplish this may be divided into two classes:—the intermittent, or settling tank, system, and the continuous system. The apparatus designed for the continuous process consists usually of a settling tank, wherein the water, after the addition of the solutions of lime and soda, is made to flow through separate spaces between series of intercepting plates in order to effect the mixture of these reagents with the water. It is then passed to the bottom of the tank through a pipe and finally rises again nearly to the top, where it overflows in a continuous stream. These conditions are varied in every possible shape and manner, and give rise to the different systems.

A properly designed continuous system is one in which the lime is fed into it as a saturated solution proportion of the flow of water. The lime treatment is completed before the soda ash is introduced, so that it can be determined whether the lime treatment is correct or not. The soda is then introduced in proper amount, with thorough mixing of water with chemicals, either mechanically or otherwise. The water should then be given ample time for settling and clarification, and finally passed through a properly designed filter for removal of the light, floating matter. This system can be used with good results under the following conditions:—

1.—When the quantity of water required is uniform or where a clear well is used to take care of the variations in the amount of water needed.

2.—Where the water is uniform in character.

3.—Where small floor space is available.

4.—Where it is impossible to obtain sufficient water to furnish the quantity of water required by an intermittent system in a limited period of time.

5.—Where very large quantities of water are required the continuous system is the best on account of the reduced floor space required, and because the system is large enough to warrant the attention of a competent man.

THE INTERMITTENT SYSTEM

The intermittent system consists of two or more settling tanks provided with mechanical stirring devices in order to thoroughly mix the lime and soda with the water in one tank, after which the water is allowed to settle, while the water in the other is being treated or drawn from it. In this system the water can be softened and purified with accuracy and uniformity.

The principal objection to this system

is the ground room it occupies and the quantity of water which must be supplied to it in a comparatively short time, to allow for treatment and settling. The necessity for using very large tanks has, in a measure, been overcome by using a filter to mechanically remove the floating sludge which does not completely settle in the time allowed in the tanks. This plan is not in any sense an obsolete one, for plants are being installed at the present time in this country among the largest manufacturing concerns. To some the settling tank plan may seem crude in comparison with the more elaborate plants working upon the continuous process.

Among the many advantages of the intermittent settling tank system are:—

1.—The absence of automatic chemical feeds.

2.—It can be operated by the engineer or his assistant without interfering with their regular work.

3.—A constant quantity of raw water is collected to be treated with a uniform amount of chemical reagents. With this plant an excess or insufficiency of chemicals is avoided, and, therefore, a uniform character of the purified water is furnished, while the simplicity of the apparatus enables an unskilled workman to obtain as good results from it as an expert chemist.

4.—The mechanical stirring results in the agitation of the raw water with the chemicals, and thus insures an intimate mixture and very materially hastens and soon completes the chemical reaction.

5.—The sludge of previous purification, which has settled to the bottom of the tanks, is mixed with the water by the action of the mechanical stirring devices. This insoluble matter moving in the water gathers together with the new, finely divided precipitate of lime and magnesia, aids chemical reaction and assists the chemicals in clarifying the water.

6.—The sludge collected in the settling tanks relieves the filter bed, so that the filter can be run from five to six times as long without cleaning as would be the case were the sludge all intercepted by the filters.

7.—Inasmuch as the settling tanks do not usually require washing or emptying oftener than once a week, the amount of wash water required is a very small percentage of the total amount purified.

8.—The water can stand for some time in order to get complete chemical reaction between the soluble impurities of the water and the chemicals added. Every chemist understands that no chemical reaction is instantaneous. If the lime and magnesia are not completely removed in the purifying apparatus they are sure to precipitate in the piping, heaters and boilers.

9.—The perfect quiet of the water gives an opportunity for complete settling and renders unfiltered water clearer than that from any other apparatus not using filters, or from exhaust steam heaters in which crude filters are employed.

10.—The operation of this apparatus is the method followed by the chemist in the laboratory, but on a larger scale and with minor modifications to suit the conditions.

11.—The arrangement of two settling tanks permits an accurate, daily record to be kept of the amount of water evaporated in the boilers. This feature will be appreciated by careful managers of large steam plants who have a regard for the coal pile.

Two tanks are usually used. These tanks are filled alternately. The chemical reagents are mixed in a small tank placed upon the top of the settling tanks, and are washed into the water while the tank is filling. The mechanical stirring devices, which consist of paddles revolved by suitable gearing and operated by power, mix the hard water and the reagents together, at the same time stirring up the sludge of previous purification from the bottom. This floats in the water and hastens the chemical reaction, and causes the new, finely divided precipitate to gather into large, flocculent or woolly flakes, enabling it to settle quickly as soon as the water stops moving.

The paddle-stirring device is the simplest and cheapest on the market. With reasonable care it cannot get out of order. It does not have to be cleaned

to be kept in working order. Steam has been tried and finally abandoned on account of the quantity required. Air, in most waters, will not do, for all contains some carbonic acid. This is just what is to be removed by the lime treatment, and the success of any purifying plant depends on the successful removal of the free or loosely combined carbonic acid, or, in other words, on a proper treatment with lime. There is also a tendency of throwing back into solution some of the carbonates, due to the dissolved carbonic acid from the air used for stirring. The paddle-stirring device can be driven by a small engine, and only in extremely large plants does it require over three horse-power.

The softened water is taken out of the tank by means of a hinged floating outlet pipe arranged to rise and fall with the level of the water, so that the clearest water is drawn from the top of the tank. This method is preferable because the water from the top carries the least amount of floating lime sludge into the filter beds, and in this way the filters can be run the longest possible time without having to be cleaned, the time varying from five to fourteen days. Naturally, the connections for filling the tanks, and also to wash out the sludge, are placed in the bottom. The washing of the settling tanks is necessary only when the sludge collects to so large an amount as to interfere with the stirring device. A pressure filter can be used in connection with these plants, the water flowing from the treating tanks to the boiler feed pumps and then being pumped through the filter into the heater and on into the boilers. If an open heater is used the water from the treating tanks flows into the heater and is pumped from the heater, through the filter, into the boilers. The water thus purified will not foam, provided the blow-off cock is used properly to prevent the concentration of those impurities which cannot be removed by any purifying system or apparatus.

This process will render the most turbid waters clear, because the large amount of sediment contained in some waters (which is found so hard to filter by the ordinary continuous process plant) is, in this apparatus, the means by which the water is clarified. That is, the mud, or sludge, assists precipitation and helps to remove that of the new raw water, which at the same time does not deposit on the filter bed and thus necessitate frequent cleaning. Properly softened and purified water not only prevents the formation of new scale, but brings about the removal of the old scale. By the continual evaporation, the water reaches a point where it can no longer hold more foreign matter in solution. Therefore, the unequal expansion of the metal and the non-conducting scale kept cool by the purified water tends to loosen the crack off the old scale. The latter then floats through the tubes and shell (there being no new deposit of lime and magnesia to further cement it). That has been the result in the different places where water purifying plants have been installed. Of course, the removal of this old scale, when using only purified water for this purpose, requires longer time; but it is accomplished with less danger to the boiler, because no injury can come to the metal from the water thus purified. There is also no danger of burning the sheets by the accumulation of scale, which would result from the introduction of some acid or other material into the water.

The removal of scale necessitates frequent shut-downs, the cost of labour and the expense of repairs, aside from the loss of energy of fuel due to the non-conducting property of scale. This depends somewhat, of course, upon the chemical composition of the scale.

All sorts of tables, and some of them from good authority, are circulated by manufacturers of so-called scale preventives, and while they are probably very much exaggerated and possibly unreliable, still, it has been proved by practical experiments that metal covered by non-conducting material must be heated to a much higher temperature in order to boil water contained therein than if the metal were clean.

There can, therefore, be no possible doubt that a scaled boiler requires the

use of more heat to generate a given amount of steam than one which is clean. Of course, the results vary with the different types of boilers, and to such an extent that no accurate table can be prepared to prove the exact amount of additional fuel necessary for the generation of a pound of steam under these varying conditions.

The purification of water before entering the boiler results in a saving in the following ways:—

1.—It saves the labour of cleaning the boilers and heaters, piping, etc. Saves the cost of repairs and saves fuel. In the latter instance the reasons are evident.

2.—The heater is kept clean and the feed water can be raised to a higher temperature.

3.—Coal is not used to heat the impurities in the water or the quantity of compound which you put in to prevent scale formation.

4.—The heat is all used in the boilers to make steam, and make it quickly and well from the purified water.

5.—Purified water keeps the metal of the boiler free from scale and loosens up the old scale in parts inaccessible to the man who enters to clean the boiler, and a higher degree of evaporation is possible than through any other means.

6.—Purifying the water is the only way which admits of getting the full benefit of the high evaporating power in water-tube boilers and furnaces in which water tubes are used for grate bars, because there is no danger of the tubes becoming filled with scale and then burning off or leaking.

Let us see what it looks like in dollars and cents for a year's run. The following statement was taken from the books of a manufacturing establishment having a 200 horse-power plant, for one year preceding, also for the second year after the installation of a water-softening system. Unfortunately, no record of the fuel saved could be obtained, as it was not considered of sufficient importance by these people, on account of the coal being taken from their own mine.

I have, however, assumed that it will require 1 ton of coal for heating a cold boiler to steam, and the evaporation increased from 10 pounds of water per pound of coal, to 10.1 pounds.

Cost of operation without water softening plant:		
Cleaning eight 250 horse-power boilers each once in two weeks, 208 cleanings per year, at $20	$4,160	
208 tons coal, at $1 per ton, to get steam on boilers cooled by cleaning	208	
Yearly extra repairs on eight boilers due to bad water	150	
Boiler compound for eight boilers, per year	300	
		$4,818
Cost of operation with water softening plant:		
Yearly cost of chemical reagents to treat 60,000 pounds of water per hour, at ⅞ cent per 1,000 gallons	$551.88	
Yearly interest, 8 per cent., and depreciation, 10 per cent., on $4,500	720.00	
Yearly cost of operating plant, at $1 per day	365 00	
Washing eight 250 horse-power boilers each once every three months, or 32 washings per year, at $8	256.00	
32 tons coal, at $1 per ton, to get steam on boilers cooled by washing	32.00	
		1,924.88
Saving by using softened water (about 63 per cent. on $4,500)		$2,893.98
2,000 horse-power boilers evaporate 60,000 pounds of water per hour, or 1,440,000 gallons of water per 24 hours. Evaporation without purifier at 10 to 1 equals 144,000 gallons; 72 tons of coal per 24 hours, at $1 per ton, a yearly cost of	$26,285.00	
If evaporation were increased to 10.10 pounds of water per pound of coal, due to having boilers free from scale, 1,440,000 gallons of water of should be evaporated each 24 hours with 71.28 toas of coal, at $1 per ton, a yearly cost of	26,017.20	
		267.80
Estimated saving, over 70 per cent. on $4,500 investment		$3,160.28

THE INDUSTRIAL ADVANCE OF GERMANY

AS SEEN THROUGH BRITISH EYES

By Joseph Horner

THE title of this article expresses an undoubted fact which is exercising the minds of many at the present time. The writer proposes to state the leading facts and features of that advance, to consider its causes, its effects, and the means by which it may be best met. Though it appears as a menace, it may prove a salutary national tonic.

The great manufacturing nations of the world are in the throes of a life-and-death struggle for industrial supremacy, the final issues of which no man may divine. Great Britain, though prosperous, sees her home and foreign trade menaced. Much attention has been directed to the American invasion, but less note has been taken of German progress. German goods have generally been deemed to be of a rather trumpery character, and the German nation has until recently absorbed at home a large proportion of her manufactured goods. Though the wants of such a large empire, having, at the time of the 1900 census, a total population of 56,367,178, are immense, yet Germany now has a steadily increasing surplus volume of goods for export, much of which finds its way into Great Britain and her Colonies, America, and other countries. The significance of this fact cannot be disregarded.

Even this, however, if it stood alone, uncomplicated by other facts, might not be so very disquieting. But behind it there is the rapid growth of the syndicates, one of the avowed objects of which is the capture of foreign markets by dumping goods on them at absolutely unremunerative prices, to balance which German home consumers have to purchase at rates considerably above those required by legitimate trading. And behind this, again, there lies the strength of the military industrial organisation of the German Empire, the strictly utilitarian system of technical training, the longer hours of labour, the lower wages, and the intense devotion to business, which, in the aggregate, constitute a very formidable phalanx for aggressive purposes.

It is not possible to foresee the ultimate extent to which a nation is able to realise its youthful ideals. Germany, like the United States, is, industrially, a young nation, with ambitions and well-defined ideals. This much is certain, — the German Empire has been moving consciously and solidly in the direction of industrial aggrandisement. Industrial and commercial pursuits have been for many years past taking precedence over the agricultural, which predominated twenty years ago. In 1882 over 8,000,000 persons derived their main income from agriculture, against 6,396,465 engaged in industry, and 1,570,318 in traffic and commerce. And the time has gone by when "made in Germany" is a byword of contempt.

Engineers are now familiar with German iron and steel, German machine tools and cranes, with the electrical industry, and with engine and shipbuilding, in each of which German manufacturers now stand second to those of no other countries, either in regard to excellence of design, of workmanship, or of efficiency. Cloth manufacturers and

others know how Germany has captured the manufacture of aniline dyes, and the indigo dyes, a good proportion of the timber trade, the clothing trade, the grocery business, the piano manufacture, and that of other musical instruments, the leather trade, agriculture, and toys. Germany is gaining ground on us more or less rapidly in these and other fields.

The industrial advance of Germany is one which illustrates the injunction not to despise the day of small things. Like the American invasion, it began with small articles, chiefly unconsidered trifles, for domestic use,—little things, the trade in which we thought we could afford to let slide. Even at the time when the Merchandise Marks Act was passed, "made in Germany" was accepted as a brand of inferiority. Out of that neglect came the opportunity of Germany's growth. British agriculture has dwindled, and still dwindles year by year, many of the lesser British manufactures are going, some have already gone, and now we wake up to find the big industries attacked. German machines shoulder those from America in British machine shops and foundries; German dynamos and motors and electrical apparatus are ubiquitous; German liners have retained the blue riband of the Atlantic for nine years past, and carry more first-class passengers than any British line does.

The growth of the foreign trade of Germany is shown at a glance by the following abstract, given in millions of marks:—

	Imports	Exports
1878	3,737	2,902
1885	2,944	2,860
1895	4,246	3,424
1901	5,710	4,512

We have here, too, an illustration of the apparent anomaly that is exercising the economists of our own nation, namely, the excess of imports over exports. The explanation is that although the value of German imports exceeds that of her exports, the former consist overwhelmingly of articles of food and raw materials for industrial purposes, while the increase in exports consists chiefly of manufactured goods on which labour has been expended.

Comparing the period 1892 to 1894 with that from 1899 to 1901, the net annual increase of exports in the latter over the former period was equal to 646,000,000 of marks per year. During the same periods the net increase of imports of raw materials for industrial purposes was equal to 519,000,000 marks per year. Herein, therefore, consists one of the elements of the strength of German industry—namely, in importing raw materials on which little or no labour has been spent, and exporting finished goods, which provide employment for the industrial population.

Almost all manufactured goods show a substantial increase in these two periods,—1892 to 1894 and 1899 to 1901. Exports of machinery lead, with an increase of 104 per cent. in value; rails, shafts, angles, ingots, etc., one of 41½ per cent.; coarse iron goods, of 75 per cent.; better iron goods, 39 per cent.; aniline and other colours, 24 per cent.; and the humble toys, 20¾ per cent. The foregoing years are selected because they coincide with the three years preceding and succeeding the working of the Caprivi treaties, in which the Bismarckian protective duties had been lowered in favour of a freer trade.

The following official figures show in a striking manner the difference in three years' recent trading between Germany and the United Kingdom, taking the years 1900 and 1902. In 1900 the value of the grand total exported by the United Kingdom to Germany, excluding ships, articles of food, drink and tobacco, was £26,406,847. In 1902 the value had fallen to £22,088,295. The value of the manufactured portion of these exports in the two years in question was £19,839,310 and £16,442,000, respectively.

On the other side, Great Britain's total imports from Germany in 1900 were valued at £31,181,667, but these had increased in 1902 to the value of £33,633,956. The manufactured portion of these imports for the two years in question was valued, respectively, at £12,933,166 and £15,320,130.

How Germany has been overtaking Great Britain in iron and steel produc-

tion is shown by the following figures:—In 1850 Great Britain produced 2,300,000 tons of pig iron, and Germany 350,000 tons; in 1902 Great Britain produced 8,517,693 tons, and Germany 8,402,660 tons. In 1850 the output of steel in Great Britain was 40,000 tons, and that of Germany 10,000 tons; in 1902 that of Great Britain was 4,929,067 tons, and that of Germany 7,373,653 tons. When the statistics for 1903 are complete they will show a further advance. The production of German pig for the first eleven months of 1903 was 9,236,886 metric tons, or 1,588,221 tons in excess of that of 1902.

The following table shows the quantities of pig iron and coal produced in Germany from 1860 to 1899, in quinquennial periods:—

QUANTITIES OF COAL AND PIG IRON PRODUCED IN GERMANY IN QUINQUENNIAL PERIODS.

Years	Population Thousands	Coal—(Exclusive of Lignite)—Total Production (Annual Average) Thousand Tons	Coal—(Exclusive of Lignite)—Per Head of Population Tons	Pig Iron—Total Production (Annual Average) Thousand Tons	Pig Iron—Per Head of Population Tons
1860-4	35,872 Census of 1861.	15,675	0.44	707	0.02
1865-9	35,872 Census of 1861.	23,942	0.67	1,165	0.03
1870-4	41,059 Census of 1871.	32,278	0 79	1,818	0 04
1875-9	42,727 Census of 1875.	39,007	0 91	2,029	0.05
1880-4	45,234 Census of 1880.	52,192	1.15	3,203	0.07
1885-9	46,856 Census of 1885.	61,888	1.32	4,006	0.09
1890-4	49,428 Census of 1890.	73,184	1.48	4,911	0.10
1895-9	52,280 Census of 1895.	90 773	1.74	6,824	0.13

A remarkable fact in the history of the importation of German steel into Great Britain is that it was non-existent so recently as the year 1899. Though Germany, like the United States, was producing largely at that time, each country absorbed its own output. But on April 7, 1890, the first cargo of German steel rails was landed at Newcastle. In October of that year Germany was offering ship plates in the North of England at £7 a ton, being about £1 a ton lower than the prices then ruling. Quotations dropped, and the German plates were being delivered in December at £6.10., British quotations falling to about a shilling or two above.

The year 1901 opened with keen German competition with steel billets and blooms, tin plate bars, and ship plates, which continued all through the year, affecting all the great rolling mill districts. The competition was accentuated by the bad state of the iron and steel trade in Germany and the financial difficulties of the German banks. Prices went lower, and many British iron and steel works passed through anxious times in consequence. This competition dealt another blow to the production of puddled bars, firms finding that they could replace iron-making profitably by rolling steel from foreign billets. The demand for pig iron and steel of home production has lessened in consequence, while manufacturers have found the cheap steel a source of profit.

To illustrate the recent growth of the German foreign iron and ironware trade, the writer would select the periods from January to June in the years 1901, 1902, and 1903. The figures are given in periods of six months because at the time of writing the official figures for the last half of 1903 are not available.

	Jan. to June 1901	Jan. to June 1902	Jan. to June 1903
Imports, tons	233,000	132,000	133,000
Value	£1,860,000	£15 269,000	£1,397,000
Exports, tons	994,000	1,504,000	1,831,000
Value	£12,006,900	£14,155,000	£16,618,000

The German imports of pig from the United Kingdom diminished during similar periods, thus:—

January to June	Tons
1900	337,58
1901	144,00
1902	58,65
1903	49,14

In three years the tonnage of pig iron imported by Great Britain from Ger-

many advanced from 4000 to 12,910 tons; of rails, from 12,900 to 38,470 tons; of malleable iron, from 12,000 to 24,000 tons; and of angle iron, from 48,980 to 74,230 tons.

Machinery and millwork is exported in small quantities from the United Kingdom to Germany, and imported in larger amounts.

	British Exports to Germany 1900	Machinery and Millwork 1902
Sewing machines	£ 178,803	£ 141,902
Steam engines	314,717	205,830
All other sorts	1,547,277	1,023.045

BRITISH IMPORTS FROM GERMANY

	1900	1902
Sewing machines	£130,398	£151,354
Steam engines	280 780	612,010
All other sorts	712.349	616,380

The last is the only group that shows a falling-off in imports. The German coal industry shows substantial advances. The recent proportions of the German foreign trade in coal, excluding lignite, are compared below:—

	Jan. to June 1902	Jan. to June 1903
Coal imports	2,826,000 tons	3,087,000 tons
Coal exports	7,147,000 "	8,187,000 "

In 1902 there were mined in Germany 107,000,000 tons of coal. The coal industry in Germany is largely organised by the Rhenish-Westphalian Coal Syndicate, which controls over 45 per cent. of the entire German coal production. It is an aggressive institution, which aims to draw into its embrace coal mines owned by independent iron and steel works. This syndicate enters into rivalry with British coal at Hamburg and in some of the North Sea ports. Fifteen years ago it controlled a production of 33,000,000 tons annually; now it controls from 64,000,000 to 78,000,000 tons. It has recently absorbed the coke and the briquette syndicates, and drawn coal-owning iron and steel works into the combination. The production of pig is controlled by several syndicates, as is that of steel, and an amalgamation of these is becoming very probable.

A big German electrical combination is that of the firms of Siemens & Halske, of Berlin, with the Schuckert Works, at Nürnberg, with a capital of £4,500,000, of which £4,000,000 are fully paid up. Two other electrical firms, with a combined capital of £4,200,000, have amalgamated, and also acquired an interest in the Körting Company, of gas-engine renown, one result of which will probably be an extension of electricity in mining, for which big gas engines driven by the waste blast-furnace gases will be required.

Outside of the raw materials of engineering and finished machinery notable German advances are also being made. Indigo manufacture has been practically monopolised by Germany. That country paid, on an average, 11,500,000 marks a year for indigo to foreign countries from 1892 to 1896. In 1902 she paid only 700,000 marks to foreign countries. The period ending with 1896 is selected because in May, 1897, that triumph of the chemist,—synthetic indigo,—came into competition with the natural product. The total value of German exports of indigo has risen since 1896 from 4,800,000 marks to 25,100,000 marks in 1902,—more than 400 per cent.,—notwithstanding that the artificial indigo brought about a reduction in prices. One factory alone, the Baden Aniline & Soda Factory, was said to have produced during 1900 artificial indigo of an approximate value of 1,000,000 marks.

The manufacture of aniline dyes and coal tar products is a department of German industry of which the export value has risen from 52,553,000 marks in 1892 to 795,631,000 marks in 1901, notwithstanding that the prices of such dyes have fallen heavily during the period.

In 1900 the value of the various chemical products and preparations sent to Germany by the United Kingdom was £306,248; in 1902 it was £239,497. In 1900 the value of similar goods sent to Great Britain by Germany was £329,891, and this advanced to £466,471 in 1902. The value of the dye stuffs and coal tar dyes imported into Great Britain from Germany was £10,782 in 1892. Ten years later, in 1902, the value of these had risen to £93,962.

An effort is being made to render the Manila rope trade independent of London, through which between 40,000 and

50,000 bales are shipped annually to Germany. It is proposed to ship it direct from Manila in German vessels. If this be accomplished, it will be by the co-operation of German shipping companies and the State railways in offering reduced tariff rates.

German wall papers are supplanting the British article. In 1897 Germany imported wall papers, chiefly of British and French manufacture, to the value of 502,000 marks. In 1901 the value of these imports had receded to 462,000 marks. In 1897 Germany exported papers worth 3,114,000 marks, and in 1901 these exports had risen in value to 5,338,000 marks.

Figures of this kind might be multiplied to show that in nearly every great department of industry German enterprise is showing substantial advances, and that America, Belgium, and British India are alike, with Great Britain, feeling its effects. In endeavouring to explain some of the reasons which conduce to these advances, attention must first be drawn to the influence of the syndicates, which, for the time being at least, loom up largest in the industry and commerce of Germany.

Syndicates play an important part in the development of German trade, while in America the "trust" is the aggressive institution. Trusts are practically unknown in Germany. Neither have they taken deep root on British soil. The difference between a "trust" and a syndicate is that the first engages in production while the second is merely a distributing agency, separating production and sale. The trust concentrates its manufacture in a limited number of mammoth establishments with the view to the cheapening of production. The syndicate, or cartel,—terms which are loosely applied to similar organisations, —limits freedom of production, while tolerating individual manufactures, and regulates sales of the products of big and little firms alike through a central office, so that producer and buyer do not come into contact with each other.

The syndicate, or cartel, may be regarded as the successor of the ancient guilds in modern life, so far as regulating supply to demand and maintaining prices is concerned. They do for national manufactures what the guilds did for local ones, with the addition that foreign markets come within the scope of their operations. Whether these will prove an ultimate evil or not, they are exercising a most vital influence at present on German trade, both home and export.

The aggressive policy of the German syndicates leads them to fix prices in an arbitrary manner. If, for instance, steel plates were being sold f. o. b. on the Tyne at £5 per ton, the German steel makers deliver similar plates on the spot at slightly lower figures. At the same time, they would sell their plates to the German shipbuilder at Hamburg at something below the cost of British plates on the Tyne, plus the freight from that port to Hamburg. The British shipbuilder thus obtains German plates at a lower price than the German builder does, while the latter, though paying a rather higher price, still gets his plates cheaper than those of British manufacture. Not only plates, but low-priced shafts and heavy forgings are now made in such quantities in Rhenish Prussia for British shipbuilders that Lloyds' Registry has four surveyors stationed at Düsseldorf to superintend and inspect this class of work.

The various syndicates which control the different iron and steel trades are, at the time of writing, working independently of one another. A well-organised attempt is being made to unite these into one vast syndicate, with a view to suppress their individual rivalries and to offer a more solid front for aggressive action in foreign countries.

Dumping is not confined to the iron and steel industries. One of the mammoth German concerns,—the Rhenish-Westphalian Coal Syndicate,—supplied the foreign market during 1900 at an average price 8.2 per cent. below the home figure. The total output for that year was 52,080,898 metric tons, out of which 5,861,978 tons were sold at the above-named dumping price. The German coal syndicates offer, too, special terms in districts where the competition

of British coal is keenest, hoping thus to oust the latter from the market.

The German syndicates weathered the recent period of bad trade by virtue of their policy of dumping abroad at low prices, aided by another artificial measure,—the granting of private bounties on exported goods. The latter, as a rule, do not exceed the difference between foreign and inland prices. But though cheap steel has been a source of much profit to many manufacturers in Great Britain, it has entailed inflated prices in Germany, and consequently curtailed the home demand.

So it comes about that the German manufacturer is handicapped in the world's markets by the foreign manufacturer, who is able to purchase the half-finished materials dumped abroad at prices lower than the German has to pay, and is thus enabled to outsell him. The artificial policy, therefore, results in curious complications. The Syndicate of German Wire Tack Manufacturers is said to have made a profit of 1,200,000 marks on the home market in six months, and to have lost 859,000 marks in the same period on foreign sales. This selfish policy entails possible issues of a very complicated character.

The syndicates boycott rival firms, and refuse to supply customers who divide their orders with firms who are not enrolled in the syndicates. The difference in the prices of the dearer home market and those for export materials interferes with the manufacture both of partly finished goods and of finished articles. The export of machines, for example, on which much labour has been expended, is clearly more conducive to a country's financial prosperity than the export of raw and of half-finished materials. Yet the policy of the German syndicates favours the latter course. It is to be concluded, therefore, that the effects of the dumping policy on German industry must be less advantageous to Germany than to the nations who receive the exported materials. Since selling under cost price has to be compensated for by increased charges to home consumers, it seems that this must have a crippling effect on the home industries if carried out on an extensive scale. If raw materials cost the German manufacturer more than the foreign one, he is at once placed at a disadvantage in the matter of international competition. And the manufacturers cannot so easily form themselves into syndicates as the groups which handle raw and partly finished materials. Hence it is found that the successful syndicates occur mostly among the latter.

German trade, though now reviving, has been passing through a very trying period. Some blame for this must be attributed to the artificial regulation of prices by the syndicates. Articles manufactured in Germany for export have been sold either at dumping or at competitive prices, the raw materials for which, including coal, have been purchased at inflated prices. The phenomena have been constantly occurring of the prices of the first receding to an extremely low figure, while the latter have been maintained at a high level. Between the high prices of materials and the low prices obtained for manufactured goods the German trades are harried. To the competition between firms tendering at home is added that of more favoured foreign firms,—Belgian, British, and American, and so, as a consequence, orders have sometimes been accepted at a loss. This explains why the syndicates who control the sale of raw materials are unpopular with manufacturers.

A result of this policy is, that as German manufacturers have to pay more for their raw materials than foreign purchasers pay to the cartels for the same articles, they resort to the practice of cutting wages. It may happen in time that many German firms will migrate, establishing branches in the countries where the German raw materials are dumped. A policy of this kind, with a view to lessen costs of raw materials, labour, and transit, has frequently been adopted by British firms, as well as others.

The German machine-tool trade, among others, has been bad,—a fact which is favourable to low prices for ex-

port orders. And the tool makers complain bitterly that by a system of "mutual contracts" the large iron works, when ordering machines, insist on a certain quantity of their own products, sometimes up to 50 per cent. of the value of the order, being taken in exchange. This presses hardly on an industry such as the machine-tool trade in which the cost of raw material is very small by comparison with labour costs. The electrical industry, which made unprecedented advances previous to 1900, has been also passing through a period of severe depression. Plant is not yet fully employed, and prices are cut. Some firms, as already noted, have been effecting amalgamations with a view to reduce expenses and check the downward fall in prices.

The whole syndicate system of trade is so artificial that forced sales of a portion of the product become unavoidable at times, simply to realise cash, which is wanted by reason of the bad state of trade at home consequent on inflation of prices there.

Four hundred and fifty German syndicates or cartels were stated to be in existence during 1901 and 1902. Of these about forty control the iron and steel trade. Competition is discountenanced and almost throttled, rotten concerns are bolstered up, rival businesses boycotted and fought.

Whatever opinion is entertained of the economical aspect of the dumping policy and its permanence, there is no disguising the fact that it is with us for the present, and will have to be taken account of by British manufacturers and steel makers. It is, for the time being, a boom to the first, and a bad thing for the second. The manufacturing firms can buy raw steel and castings and forgings at considerably less,—from 10 to 30 per cent.,—than the cost of similar products made in Great Britain, and export the finished work, the orders for which, but for dumping prices, they could not have secured.

Meanwhile, the period of bad trade from which Germany has been suffering seems to be passing away. The railways are carrying more goods, and the foreign trade is much larger than in 1901 and 1902. The exports for the first six months of the last three years are compared below.

Jan. to June	Tons	Value
1901	15,000,000	£106,000,000
1902	15,800,000	111,100,000
1903	18,300,000	120,500,000

Fluctuations in trade from year to year may, however, be regarded simply as the waves borne on the great tides of national advance. A broader view takes note of the steady rise of the tides, and seeks to understand the great forces which produce them. The wonderful and rapid transformation of an agricultural nation into an industrial one, which is taking place in Germany, with all collateral and subsidiary issues, is the main point. We observe the steady growth of her exports and the strength of her competition, fostered by the powerful syndicates and their policy. The scheme of national education is directed definitely also towards one utilitarian object,—the advance of industry and commerce.

At the present time it is well to have clear ideas of the dominating elements that make for industrial supremacy. The subject is extremely complex, and any statements offered are open to criticism. Even experts are divided into cliques, some of which rank the efficiency of labour first; others place machinery foremost; still others pin their chief faith to technical education. Each view would be correct if limited to certain branches of industry, but wrong in others.

Taking a broad view, however, we should be justified in saying that skilled labour, though a vital element, is of less relative importance now than formerly; that machinery is becoming, or has become, the predominant factor; and that technical education, if of the right sort, occupies a position of considerable importance, but one of which it is easy to overrate the value in some departments of industry.

With regard to labour, the British workman is able to hold his own against the mechanics of any country. But as a set-off, his wages are high and hours short. But there is an unrest of labour

in Germany which has for its object higher wages and shorter hours. Still, a long time must elapse before it reaches the British standard. A nine-hour day and a ten-hour day are still a dream of the German workman, as is a minimum wage of from 5½d. to 7d. per hour for skilled hands. But we can hardly hope in our tight little island to meet united Germany in the years to come on terms of equal expansion, with her 56,000,000 of inhabitants, increasing yearly by over 600,000, and her still great reserve of agricultural population to draw upon.

With regard to machinery, we cannot now claim any advantage in the possession of this, because it is not as though it were the product mainly of one country; it belongs to all countries alike.

Technical education in Germany is more extensive and better organised than it is in Great Britain, and therein lies an advantage. But our own system can be improved if the right men are entrusted with the task, and if the ultimate object to be obtained,—*i. e.*, greater productive power,—is borne in mind.

The industrial advance of Germany is generally attributed in the main to her system of technical education. But the writer holds that, while true of some industries, this does not afford a satisfactory explanation of the growth of others. German steel, for example, is brought here because it is cheaper than the British-made product; and this is due not to education, but to the policy of the syndicates. Many German machine tools and small tools and appliances are close imitations of well-known American articles, and here technical education is not in question.

German mechanical toys sell here simply because British firms have neglected this branch of industry. We eat German potatoes for the same reason that we buy Canadian apples or French eggs, because Great Britain takes little care of these industries, preferring town life to agriculture, and football and cricket to proper attention to business.

On the other hand, the growth of the dye industries is distinctly a result of a high training in chemistry. The story of how these industries have been lost to Great Britain is well known. And if we take again machine tools, we find that while there is much imitation, there is also a very large proportion of machines which are original in design, and unrepresented as yet outside of Germany. Technical training, in combination with practical knowledge, must be credited in a large measure with these results.

The artificial measures of the syndicates designed to capture foreign markets may or may not be permanent. The cartels, like men, may come and go. But a wider question is that of the mechanical genius of the nation. Are the Germans likely, judging from present evidence, to achieve permanent and advancing success in the production of the raw materials of manufacture, and in the economical construction of mechanism of all classes? The answer must, without a doubt, be in the affirmative. Let us glance rapidly both at some of the work Germans have done and what they are doing.

All the conditions which favour permanent success are apparent in German industrial life. In the first place, education is intensely practical. If a youth is intended for a mechanical career, his whole training, from earliest life, is bent in that direction. The schools make him familiar with the work of the shops and prepare him to understand its principles and practice.

An English lad, going from school to the shops, generally comes into a strange world,—one of which he is profoundly ignorant. Too many begin their career with more interest in sport than the work by which they have to earn their daily bread. Whether an advanced technical training and an absolute devotion to work is better than the British system, from the point of view of character and versatility, is a problem not to be discussed here. But certainly the German system is eminently favourable to the rapid advance of German enterprise.

Again, the recently-built German factories are designed after the best modern models, and are equipped with modern

tools and appliances. The influence of the best American factory design is apparent in them, as it is in many of those newly built in Great Britain. Light, ventilation, regular progression of work through successive departments, a good service of cranes and trolley tracks, and altruistic provisions for labour are apparent in the later-built German works.

If now we consider certain leading departments of manufacture, we find that the German firms are not only to the fore in these, but that there is no conceivable reason why they should recede from that position. When the steel invasion began in 1899 complaints were made that the material was not equal to the British product; but it has been, and is still being, used extensively in British rolling mills. The German steel works are equipped with the best modern machinery.

If we look at the growth of machines and machine tools, we note two prominent facts,—one, that Germans are excellent imitators; the other, that they are equally good originators and inventors. The British purchaser who buys machines of the agents for German tools is not always aware of their origin. Vast numbers of cheap German emery-grinding machines, drilling machines, and other tools have been sold in Great Britain for many years past. High-class goods, however, are mostly well known, and ordered from the makers, either through agents or direct. A good deal of second-class machinery is sold, which is built after models that are popular both here and in America, and thus a market is obtained in shops that cannot afford the high-class originals.

But imitations do not constitute so large a section of German manufacture as do machines of independent design. There is hardly a type of machine tool which is not being specialised by German firms,—lathes, drills, planers, millers, grinders, and the rest, and many of them are marked by a grade of workmanship equal to any in Great Britain. It requires no argument or proof to point to the fact that the centre of gravity of workmanship has changed in consequence of the growth of new machines and the processes which they embody. Good workmanship is no longer primarily a question of handicraft, but of machine finish. The turret lathe, and automatics, the milling machine, the gear cutter, and the grinder have been the principal agencies in bringing about this change. The production of new machines is thus cheapened, the cost of repairs and renewals is lessened by the interchangeability of parts, and durability is increased by the practice of hardening surfaces that are in sliding contact, which grinding renders possible.

The high degree of precision attained in the improved modern machines reduces the demand for highly skilled craftsmen, and it is easier to train experienced attendants than skilled workmen. The German shops, with their equipment of machine tools, are fully abreast of this modern movement, and the German rivalry will, therefore, not be likely to prove of a transient or spasmodic character.

Another important department is the production of instruments for fine measurement, and this has been taken up by the Germans to an extent which renders them very serious rivals to the American firms who trade in this class of work. Great Britain is doing practically nothing in this branch, that is, the number of firms engaged is extremely limited, so that the micrometers of all kinds, gauges, rules, verniers, and cognate precision instruments that are chiefly used, even in British shops, are of American or German manufacture. Many of these German-made tools are cheap, with the usual concomitant of cheapness. But others are costly, and of a high grade of excellence. Many are exact imitations of American models.

But outside of these there are large numbers of measuring instruments which are modified in fashions that have no counterpart in American designs. Many, too, are designed for a rather limited class of work, as for locomotive shops. Everything points to the probability that the Germans will, in the course of a few years, capture the British market for this class of work, largely ousting the American goods from it.

It is possible that more may be done in Great Britain to secure the trade in these high-class instruments, but the indications of such a happening are very few at present.

Crane-making is a German industry of rapid growth. It is developing concurrently with electrical work. This helps to explain why so large a proportion of German cranes are of the electrical type. The growth of German shipbuilding and of foreign trade has had much influence on crane design of the long-arm and of the portal types. Although the exportation of complete cranes to Great Britain has not reached considerable proportions, the number of British-built cranes which have been supplied with German motors and equipment is large.

A department in which Germany is making immense strides is that of moulding machines and foundry plant in general. This is a class of work which has been greatly neglected in Great Britain, and the result is seen in the fact that shops over here which are equipped with moulding machinery have, in a large number of instances, laid down those of American or German manufacture. Hand, hydraulic, and pneumatic machines are each made in large quantities in Germany. Some are of a very massive character. Some are entirely special in their applications, the changes being rung in many ways, to suit all requirements. Core-making machines, ladles, special kinds of moulding boxes, and other foundry appliances are manufactured in large quantities.

Locomotive building is a growing German industry. The Börsig works, near Berlin, are in the forefront as iron and steel makers and locomotive builders. This firm alone has constructed 5300 locomotives. The yearly output of coal of the firm is over 780,000 tons; of pig iron, 50,000 tons; of steel plates, 22,000 tons; of steel ingots and castings, 43,000 tons; and there are other items.

German shipbuilding also shows a notable advance, the significance of which seems hardly to have been realised yet in Great Britain. It is not merely that the German liners have taken the lead of those owned by British companies, both as regards speed and number of passengers carried, though this is very striking. The larger fact is, first, that Germany builds her own liners, instead of ordering them in Britain, as formerly; and that in proving herself thus capable of this task she possesses boundless potentialities for the future. Steel and coal, technical skill, and gathered experience, shipyards, ports, and rich precedents,—everything that makes for permanent advance is there.

The North German Lloyd was originally an amalgamation of four shipping firms of Bremen, amalgamated as far back as 1857, with a capital of 4,000,000 marks. Not until 1880 did the fluctuating fortunes of the line result in a position of assured success. The magnificent fleet of this company now includes 122 steamers, with a tonnage of 583,000. Forty-one of these are ocean steamers, and of these thirteen are of over 10,000 tons each.

And when writing of German shipbuilding the Vulcan Shipyard at Stettin deserves mention. These works date from 1851, as a private concern, occupying then an area only one-tenth of the present works. Now they give employment to 7500 men, and 261 ships have been built there, besides 2000 locomotives. The shipbuilding record comprises 66 warships, 146 screw steamers for the mercantile marine, and 49 paddle steamers. These include many well-known vessels, the *Kaiser Wilhelm der Grosse*, the *Kronprinz Wilhelm*, the *Kaiser Wilhelm II.*, and the *Deutschland*, the performances of which are well known. During the six years from 1896 to 1901, inclusive, the average displacement of the vessels constructed was 251,300 tons per annum, and the machinery 64,500 I. H. P. A central power station supplies energy to about 300 electric motors in the works, ranging from 75 H. P. to those of ½ H. P. for portable tools.

German shipbuilding in iron and steel dates from 1886 and 1887, when the Vulcan Company constructed six mail steamers for the North German Lloyd.

The German mercantile marine in 1903 comprised 1425 steamers of over 100 tons, with 2,794,311 gross tonnage, and 473 sailing vessels of 488,936 net tonnage. German shipbuilding, as the following figures show, is a steadily growing industry:—

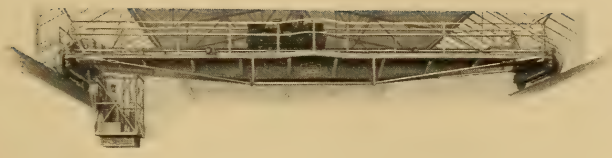
	1900	1901	1902
Tonnage	260,751	284,063	396,433

During 1902 the two great German lines carried about the same number of cabin passengers as the three great British and American lines, as the following table shows:—

PASSENGERS LANDED AT NEW YORK BY FIVE PRINCIPAL LINES

	1902		1901	
	Cabin	Steerage	Cabin	Steerage
North German Lloyd	27,767	110,697	22,960	101,384
Hamburg-American	20,698	98,988	20,977	78,570
White Star	18,402	40,225	18,167	30,483
Cunard	16,308	23,650	17,783	19,943
American	14,456	20,658	12,110	12,511

It is to be concluded, therefore, that the German industrial growth is one of which the foundations are laid broad and deep in the national life and character, and one which will have to be taken account of in the years to come. It is not of a spasmodic character, but of steady growth. Great Britain possesses no advantages which Germany does not also possess. In view of these facts, it is a pity that British statesmen give so much to party that should be given to progress. Much might be done by a practical government that cannot be done by individuals. But these also have a duty to perform to themselves and their descendants. We inherit a glorious past, and strong, earnest national ideals are wanted more than ever now, if Britain is to retain a worthy position in the forefront of the nations.



ELECTRIC POWER IN BRITISH SHIPYARDS

WITH SPECIAL REFERENCE TO THE NORTH-EAST COAST

CONCLUDED FROM THE MARCH NUMBER

By C. S. Vesey Brown, M. Inst. C. E.

ONE of the important operations in the building of a ship is the handling and hoisting of the heavy plates, angle bars, and girders after they have been prepared by the machine tools. Not only must these plates and bars be hoisted into position on the framework of the ship, but they must be held there while they are marked off for cutting or riveting, so that it is most important that quick and easy means should be provided for this work. It is also essential that the hoisting gear should be capable of being operated without any loss of time or without any particularly skilled attention on the part of the operator, and, further, it is necessary to supply him with efficient brake power and means of releasing the load at the right moment.

A winch and derrick are usually employed for this work. The winch in the old days was operated by steam, but now it is worked by electricity. Figs. 16, 17 and 18 show different types of winches which are operated electrically, and from their general appearance it will be seen that it is not a difficult

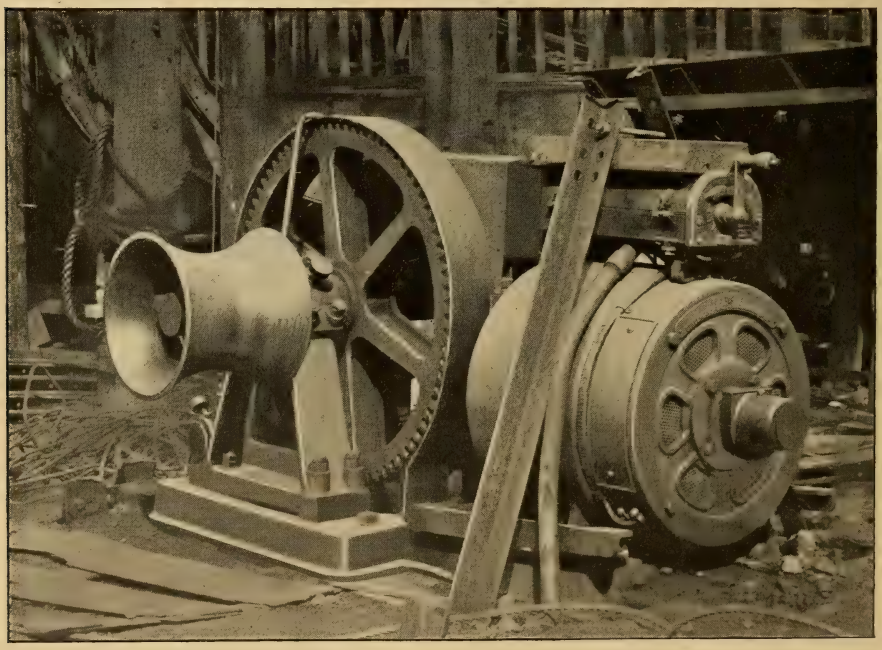


FIG. 16.—AN ELECTRIC WINCH MADE BY THE SUNDERLAND FORGE & ENGINEERING CO., LTD., OF SUNDERLAND

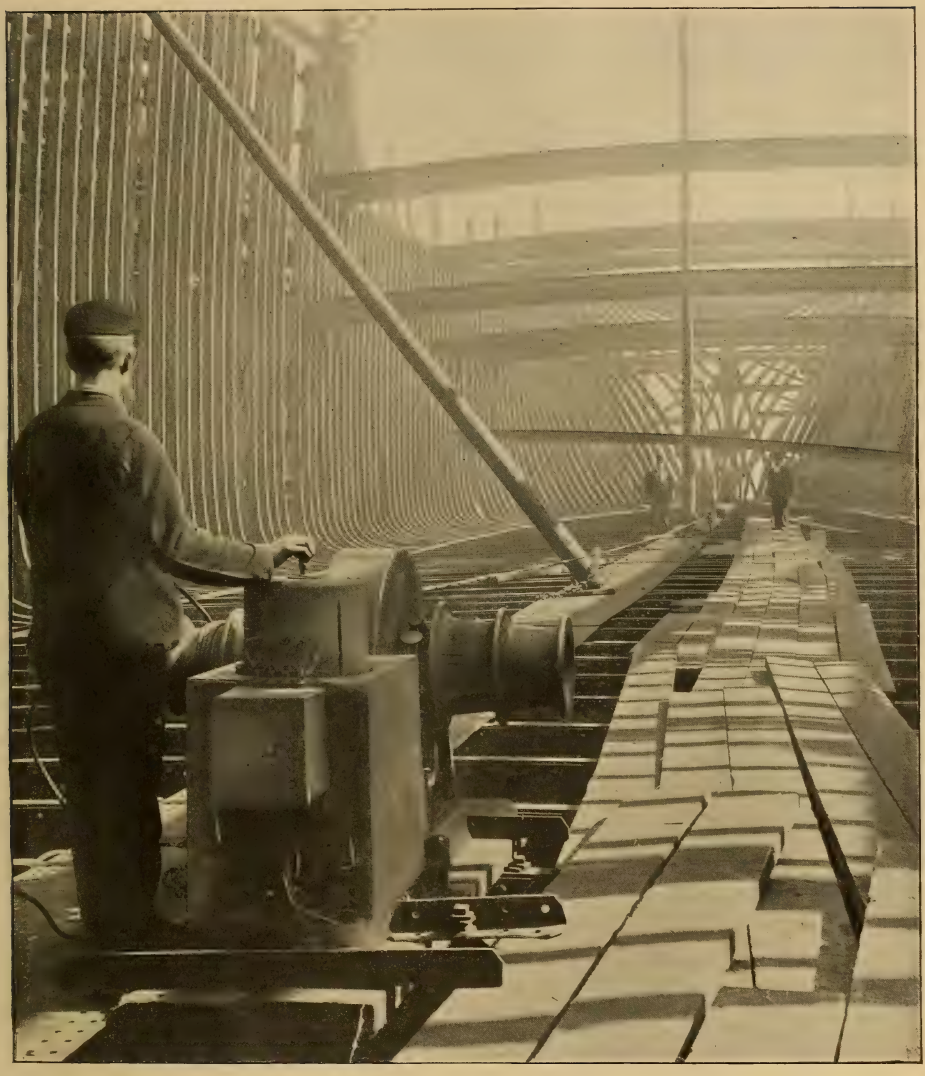


FIG. 17.—A SERVICE VIEW OF THE WINCH SHOWN IN FIG. 16

operation to move one of these tools to any convenient spot to deal with any altered conditions of the work, especially as the size and type of ship vary from time to time.

The winch shown in Fig. 16 is driven by a series-wound motor, and is fitted with a controller similar in appearance and design to a tramway motor controller, so that the operation of hoisting can be carried out at varying speeds and the direction of rotation of the drum reversed if required. The winches are provided with efficient foot brakes, which can be used from either side of the winch, and this, in conjunction with the electric brake, allows a good margin of safety in the work.

The winch shown in Fig. 18 is driven by a three-phase, alternating-current motor, and its controller handle is connected to both the controlling and reversing cylinders, so that the operator does not have to think of two opera-

tions when working the winch. These winches allow of a speed of from 25 to 50 feet per minute, depending on the weight and size of the warping drum. Fig. 19 shows a pattern of winch supplied for use on board ship, which is also used in shipyards. It is of a heavier design than the other winches illustrated. There are two notable examples on the Tyne of shipyards in which special attention has been paid to the rapid and efficient handling of the material used in shipbuilding. These are the yards of Messrs. Swan & Hunter and Messrs.

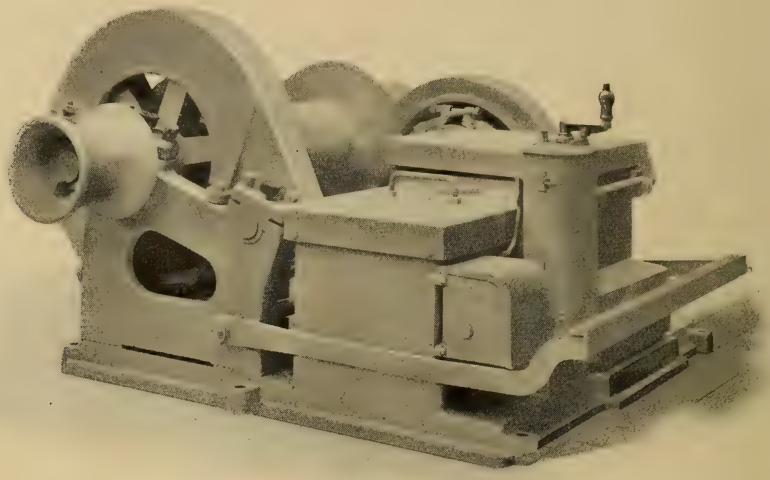


FIG. 18.—A WINCH DRIVEN BY A BRITISH THOMSON-HOUSTON COMPANY THREE-PHASE MOTOR AT SIR W. G. ARMSTRONG, WHITWORTH & COMPANY'S YARD AT WALKER-ON-TYNE

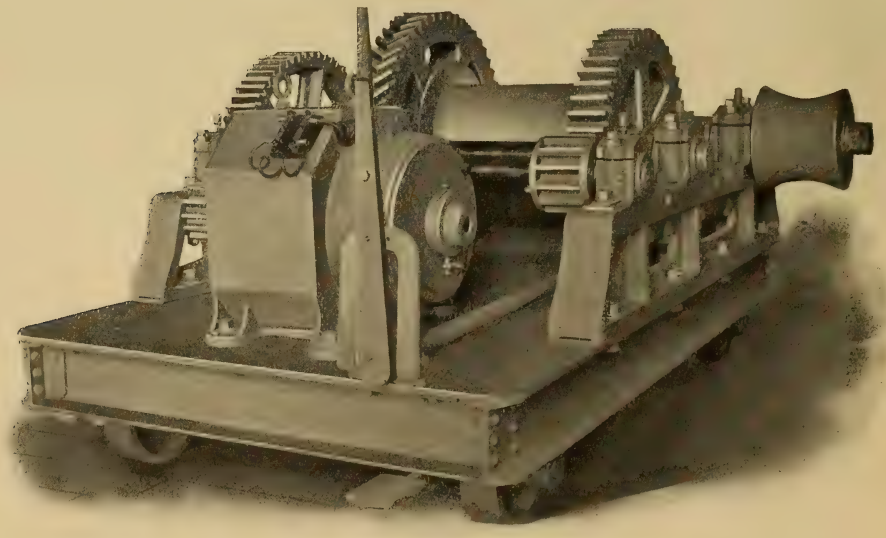


FIG. 19.—A SHIP WINCH DRIVEN BY A CONTINUOUS-CURRENT MOTOR SUPPLIED BY MESSRS. BRUCE PEEBLES & CO., LTD., EDINBURGH

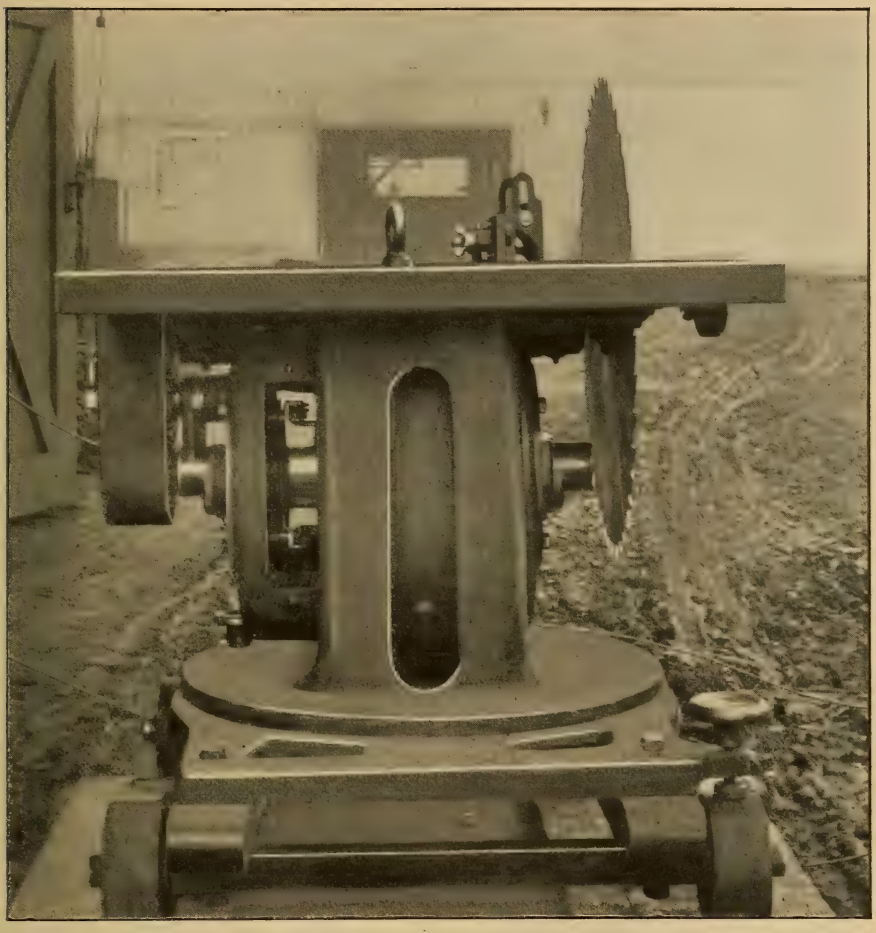


FIG. 20.—A PORTABLE CIRCULAR SAW IN THE YARD OF MESSRS. J. L. THOMPSON & SONS, LTD., SUNDERLAND, DRIVEN BY A CONTINUOUS-CURRENT MOTOR SUPPLIED BY THE SUNDERLAND FORGE & ENGINEERING CO., LTD.

R. Stephenson & Co., Ltd., and inasmuch as the two yards are practically opposite to each other on the river, the difference of practice is all the more noticeable and interesting. Messrs. Swan & Hunter's arrangement dates back to the commencement of the firm's adoption of electric power, and is coincident with their well-known and unique covered-in building berths which form such a prominent landmark on the north side of the river Tyne.

Fig. 21 is a very good view of one of the berths, and shows the two overhead cranes which run the whole length of the 500 feet which constitutes the covered-in portion of the berth. The tracks on which each crane runs are set at the same slope as the ways, namely, 1 in 50, and in order to stop the crane when running at the maximum speed of 300 feet per minute on this gradient an electrical brake operates on the upper shaft by means of a switch conveniently placed to the operator. The tracks are of 12 feet gauge, and are at 22-foot centres from the centre of the building. This allows both cranes to deal with material over the entire 68-foot width of the building.

The cranes are each operated by a 25 H. P. shunt-wound motor at 125 volts,

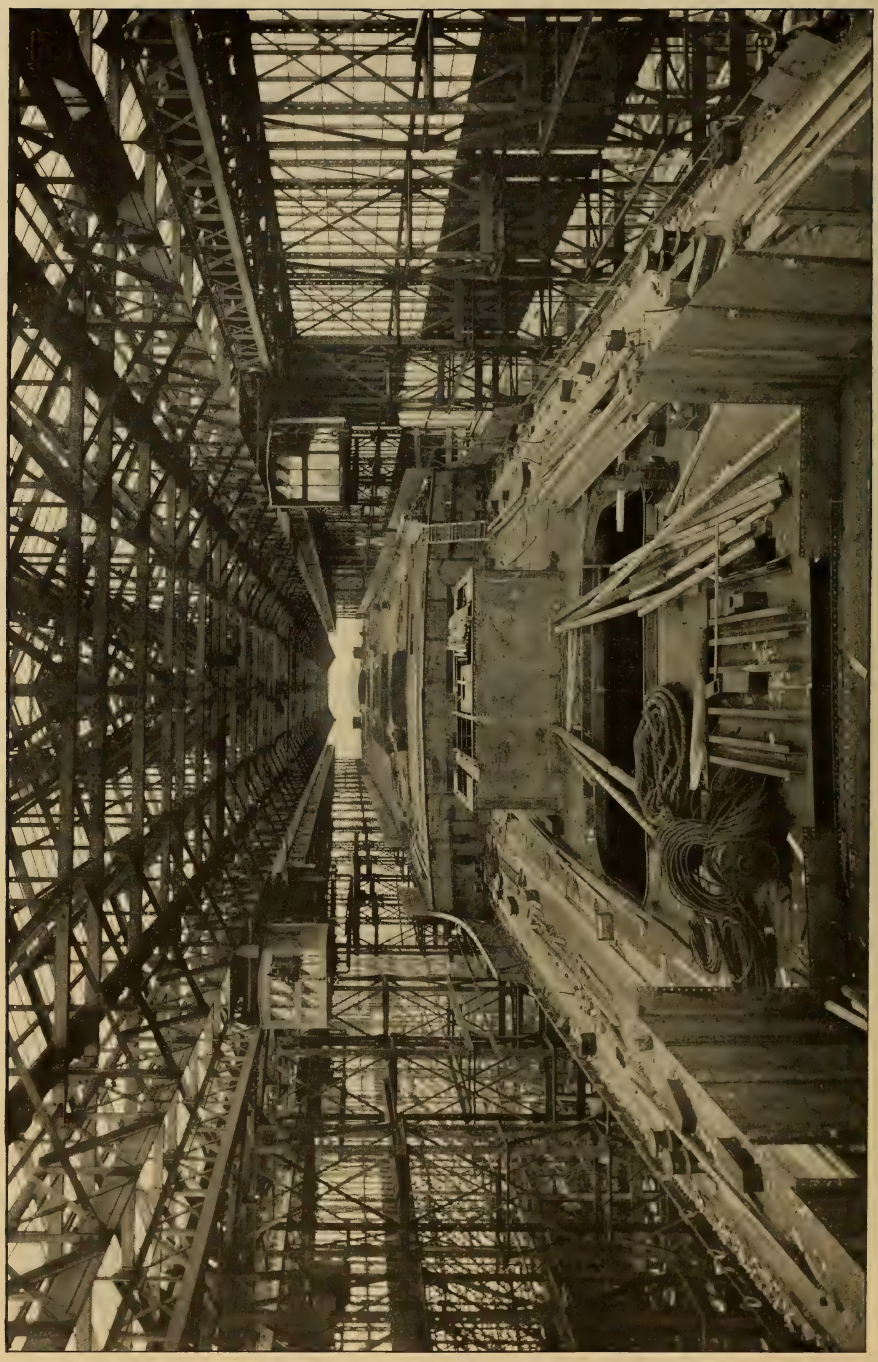


FIG. 21.—ELECTRIC CRANES IN ONE OF THE COVERED BERTHS OF MESSRS. SWAN & HUNTER, AT WALLSEND. THESE CRANES WERE MADE BY MESSRS. CLARKE, CHAPMAN & CO., LTD., OF GATESHEAD

which is used as a counterweight to the jib, being mounted on an adjustable frame. The current is collected by insulated contact rings sliding against bare conductors fixed on each side of the track. The power taken by the crane to ascend the track against the gradient of 1 in 50 is about 6 H. P., and as each crane weighs about 14 tons empty, special brackets are provided on the frame so that in the event of a wheel fracturing, or other accident happening, the crane will drop on the rails about ½ inch away. Special precautions also are taken to release the jib, in the event of a plate catching in the framework of the ship or the weight being too heavy, by the release of a trigger as soon as the rope sheave has exceeded its play of 3 inches. The action of tripping this trigger cuts off the current from the motor and at the same time puts the belt on the loose pulley. The regulating resistances allow of any speed for hoisting from 32 feet to 100 feet per minute with loads of from 30 cwt. to 3 tons.

Messrs. Swan & Hunter have also in use a single cantilever crane running on the roof of one of the berths along a track of which one rail is fixed in the gutter and the other on the ridge of the roof of the building. This crane, which was made by the same makers as those inside the building,—Messrs. Clarke, Chapman & Co., Ltd.,—is worked on practically the same principle as those already described, and is used to handle the material on a third berth which is open to the air and alongside the covered-in berths.

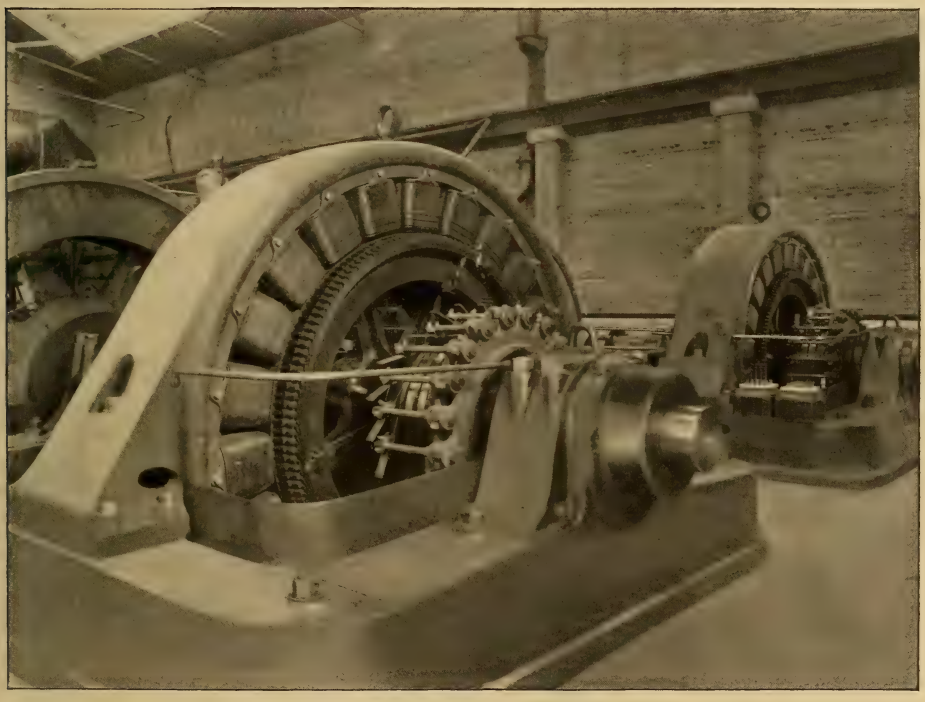


FIG. 22.—WESTINGHOUSE THREE-PHASE GENERATORS IN THE POWER STATION OF PALMER'S SHIPBUILDING & IRON CO., LTD.

It needs little thought to appreciate how impossible it would have been to work any such arrangement as has been put up at Messrs. Swan & Hunter's yard by other means than electric power, especially from the point of view of economy. To have employed steam would have entailed very much heavier

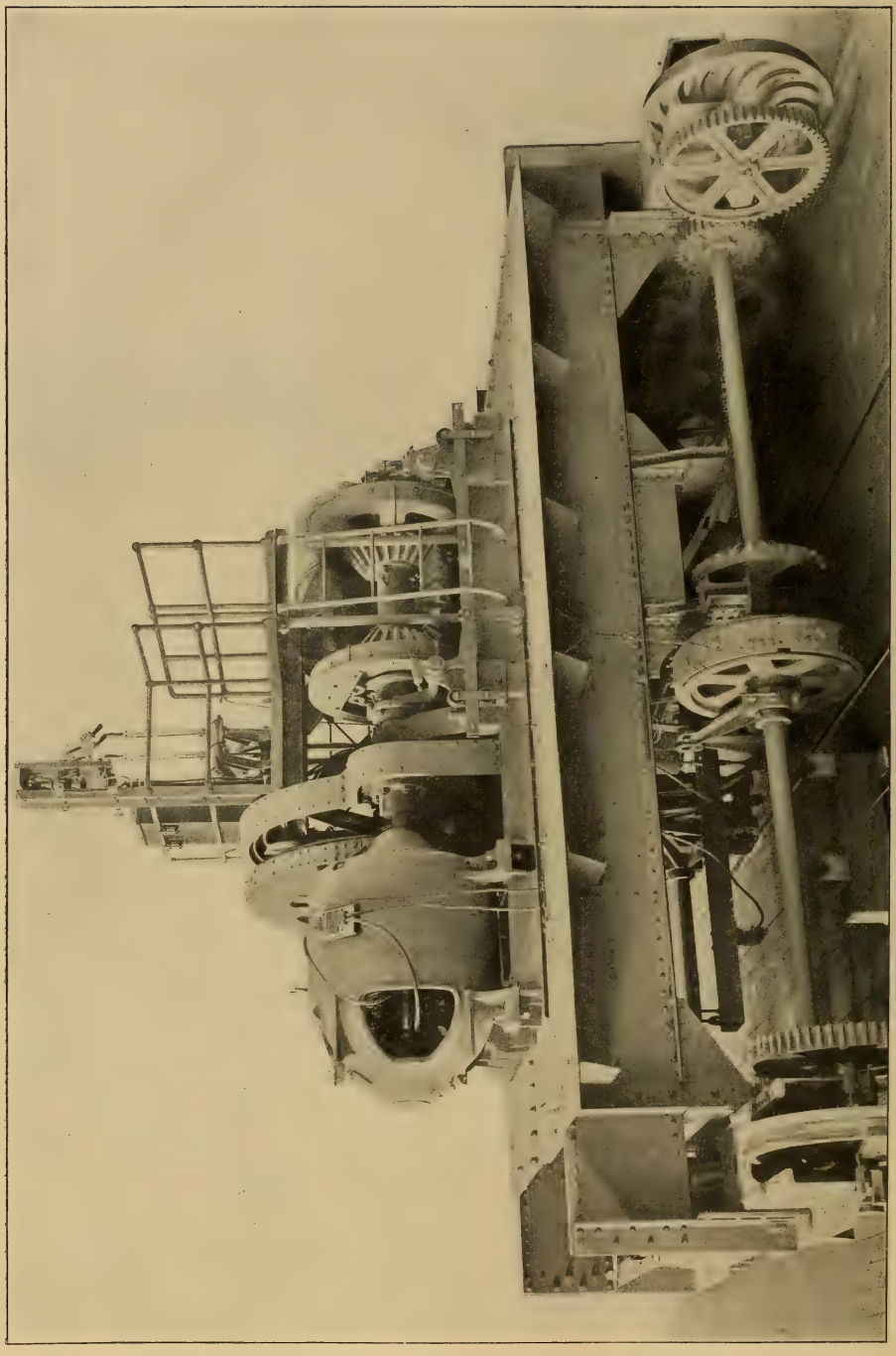


FIG. 23.—MOTOR AND TRAVELLING CARRIAGE OF A CANTILEVER CRANE AT THE YARD OF MESSRS. R. STEPHENSON & CO., LTD., HEPBURN-ON-TYNE, MADE BY THE BROWN HOISTING MACHINERY CO., LONDON AND CLEVELAND, OHIO, U. S. A.

FIG. 24.—ANOTHER VIEW OF THE SAME CARRIAGE, SHOWING THE SWITCHES AND CONTROLLERS

roof work, besides all the difficulties attendant on the conveyance of coal and water to the cranes and the removal of the ashes after the coal was burnt, etc.

The other interesting application of electric power to hoisting gear is the double cantilever crane and gantry which has been put up by the Brown Hoisting Machinery Company at the yard of Messrs. R. Stephenson & Co., Ltd., Hepburn-on-Tyne. Figs. 30, 23 and 24 show the crane and its carriage. The motor is operated by continuous current, is shunt-wound, and is designed to allow the crane to hoist up to 10 tons at a speed of 125 feet per minute for a distance of 50 feet along each arm of the cantilever. The maximum weight which can be lifted at the extreme end of the arms is 3 tons, and as the effective reach of these arms is 89 feet, it will be seen that there will be no difficulty in handling material for the largest ships now being built.

The crane is so designed that it will carry the heaviest load at a speed of 350 feet per minute against a wind pressure corresponding to 30 miles an hour, and as the speed across the cantilever arm is from 400 to 800 feet per minute according to the load, little time is lost in transferring the hoisting carriage from one

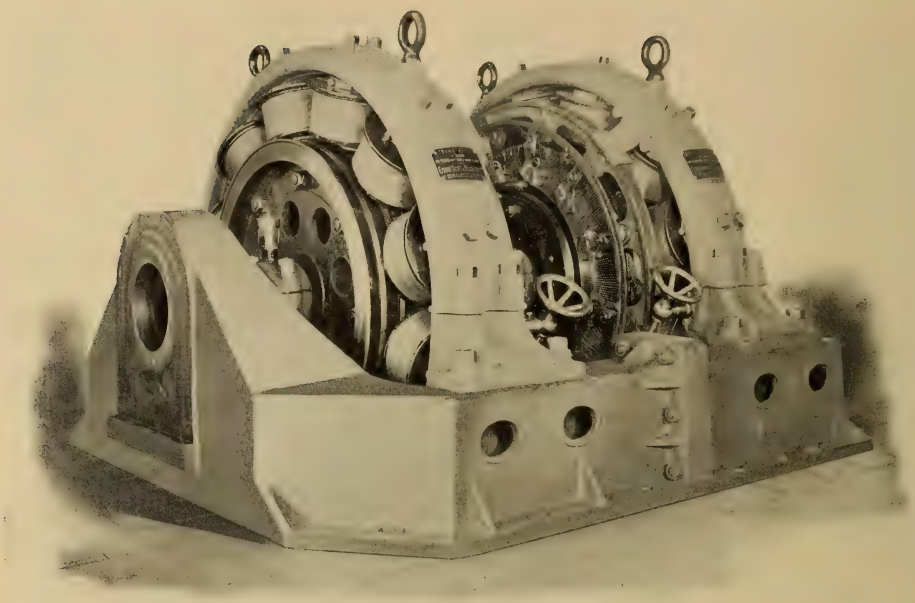


FIG. 25.—TWO 140-H. P. CONTINUOUS-CURRENT MOTORS MADE BY MESSRS. ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON-TYNE, USED FOR DRIVING CENTRIFUGAL DOCK PUMPS AT THE BLYTH SHIPBUILDING COMPANY'S DRY DOCK, AT BLYTH

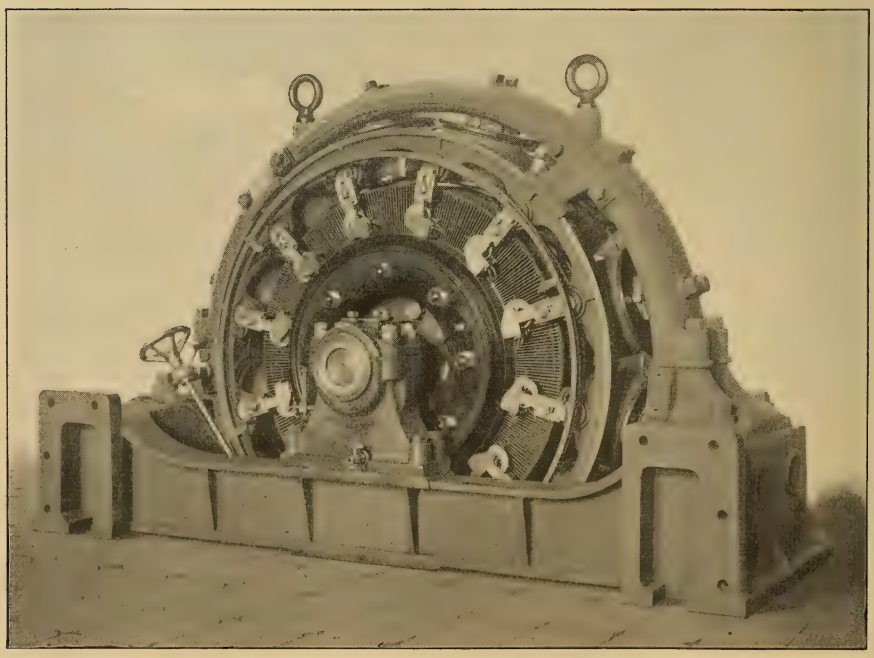


FIG. 26.—A VIEW OF ONE OF THE MOTORS IN FIG. 29, SHOWING THE COMMUTATOR AND BRUSH GEAR

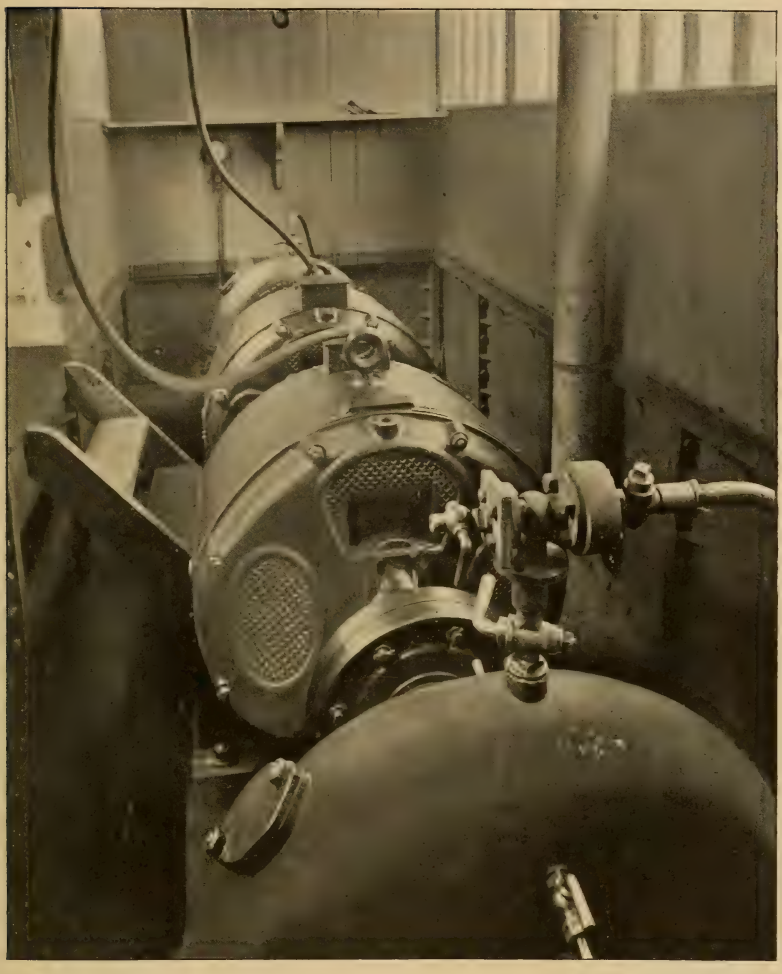


FIG. 27.—WESTINGHOUSE THREE-PHASE INDUCTION MOTORS DRIVING CIRCULATING PUMPS FOR CONDENSING PLANT AT THE YARD OF PALMER'S SHIPBUILDING & IRON CO., LTD., JARROW-ON-TYNE

side of the gantry to the other. In this manner there is no difficulty in dealing with the building of two ships at once, as was intended when the crane was put up. The same type of crane has been erected at the yard of Messrs. Vickers, Sons & Maxim, Ltd., at Barrow. As the crane is operated by one man and takes very little more power than the cranes already described, there appears to be considerable advantage in this method of handling the material for two ships as against that in vogue at Messrs. Swan & Hunter's yard; but, on the other hand, if there is much holding-up to be done, then the four-crane arrangement has the advantage.

As hydraulic work forms a considerable part of the art of shipbuilding, it is necessary to provide an extensive pumping installation in a shipyard to supply the numerous hydraulic riveters, flanging and punching machines, etc. For this purpose either direct-acting or three-throw pumps are employed. Fig. 28 shows how the latter type of pump is operated electrically at the yard of Messrs. Furness, Withy & Co. It will be seen from the illustration that the striking gear which operates the motor

starting and stopping switches is placed so that as the accumulator ascends to its full height, or lowers as it is emptied, it operates a small piston supplied from the accumulator, which, as soon as the motor is started and is up to speed, throws the belt on the pumps on to the fast pulley and throws the full load,—in this case 40 H. P.,—on to the motor, reversing the operation when the accumulator is full.

As this cycle of operations takes place many times in the course of a day's work and at varying intervals, there is a considerable strain on the motor, which has to run practically without attendance beyond occasional oiling up. From the appearance of the commutator and brushes of the motor shown in the illustration after about five years' work, it would appear that Messrs. Furness, Withy & Co. have solved the problem of building a sparkless shunt-wound motor.

While on the subject of riveting, which is done entirely by hydraulic riveters, or, in inaccessible places, by hand, it is worth noting that no attempt has apparently been made to introduce electric riveters into shipyard practice in Great Britain, though there are numerous examples in engineering works on the Continent of Europe. There ought not to be much difficulty in operating a small series-wound motor for this purpose, and for repair work or in places inaccessible to the heavy hydraulic machine a small electric riveter would be of considerable service.

After the ship has been built and launched, there is a considerable amount of woodwork to be done. Fig. 20 shows a portable electric saw bench, such as is used when laying ceilings, for example. The saw is mounted on a trolley, to enable it to be wheeled to any part of the ship, and the provision of a turntable on the frame allows the top part of the machine to be turned to any desired angle without altering the base, so that short or long special pieces of timber can be dealt with in confined places. The machine is compact and handy. A difficulty which confronted the

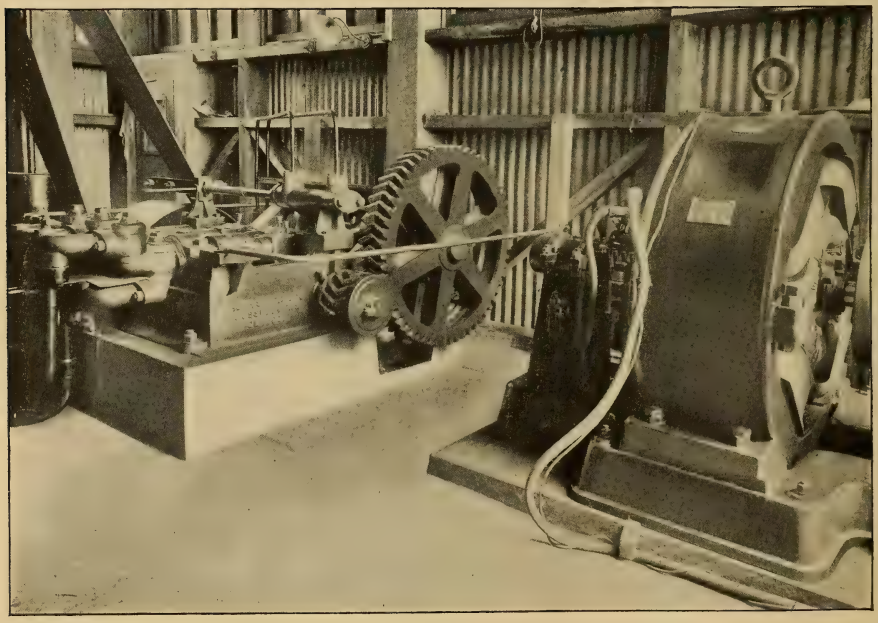


FIG. 28.—A MOTOR-DRIVEN THREE-THROW PUMP FOR CHARGING HYDRAULIC ACCUMULATORS AT THE YARD OF MESSRS. FURNESS, WITHY & CO., LTD., HARTLEPOOL

shipbuilder when he started to equip his yard with electric motors was that of dealing with the supply of steam to his steam hammers, and until the atmospheric power hammer shown in Fig. 29 was brought out, there still remained the losses due to long steam pipes to the steam hammers. The principal operation of the hammers is the drawing-out of wedges, and as the hammer illustrated can give about 165 blows a minute, or about the same as a steam hammer, the difficulty is removed. The hammers take from 12 to 20 H. P. to drive them.

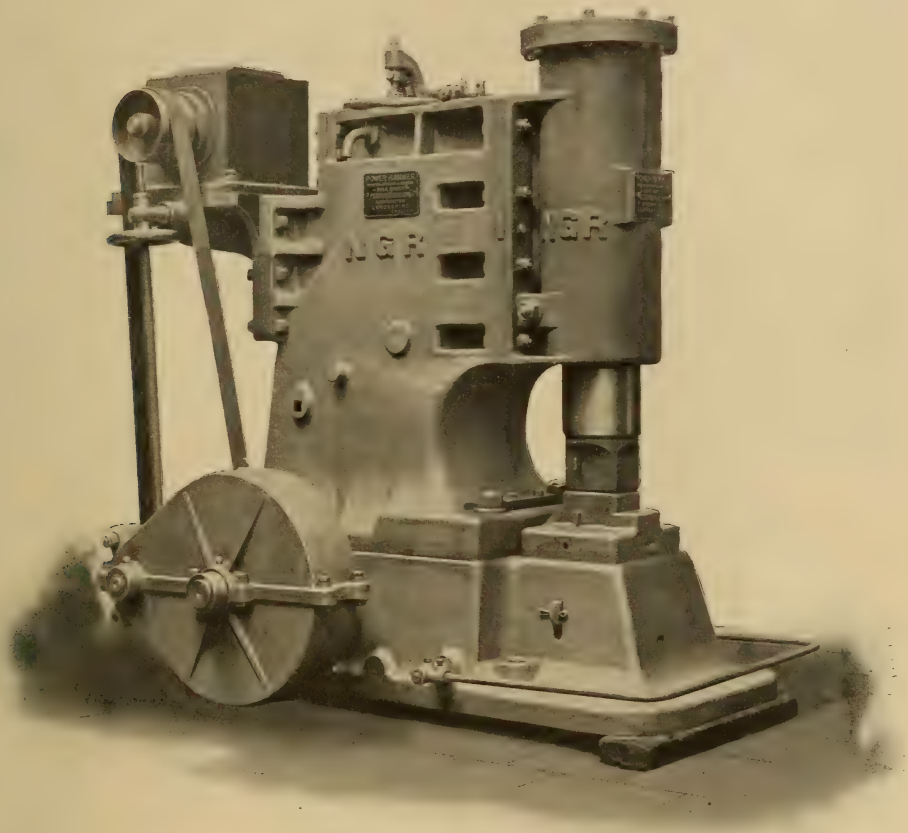


FIG. 29.—AN ELECTRICALLY-OPERATED HAMMER MADE BY PETER PILKINGTON, LTD., ACCRINGTON. A 16 H. P. MOTOR IS USED

Other applications of electricity in shipyard practice include the use of electro-deposition plants for galvanizing stanchions, rails and other exposed ironwork which is likely to be rusted. This work is, as a rule, carried out by low-tension dynamos, run at a very low voltage and large current capacity. The repair of faulty castings is also a feature of the equipment of some yards, and by the aid of a low-tension dynamo and carbon pencils it is possible to fill up holes and flaws in such castings.

Though not connected with shipbuilding, the possession of a dry dock is very often an adjunct to a shipbuilding yard, and it is not out of place to mention one or two examples of this class of work. At Palmer's works, at Jarrow, the dry

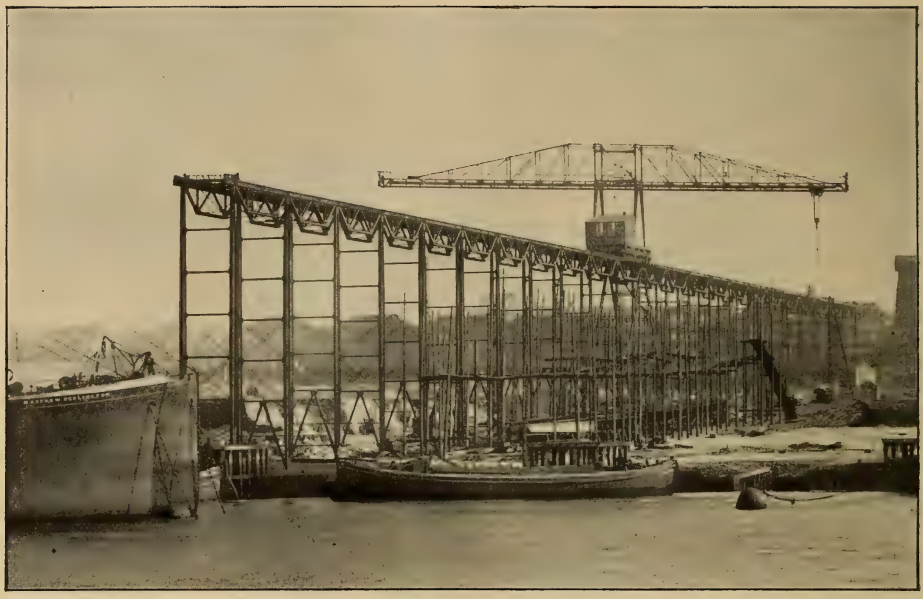


FIG 30.—A DOUBLE CANTILEVER ELECTRIC CRANE BUILT BY THE BROWN HOISTING MACHINERY CO., LONDON AND CLEVELAND, OHIO, U. S. A., FOR THE SHIPYARD OF MESSRS. R. STEPHENSON & CO., LTD. HEPBURN-ON-TYNE

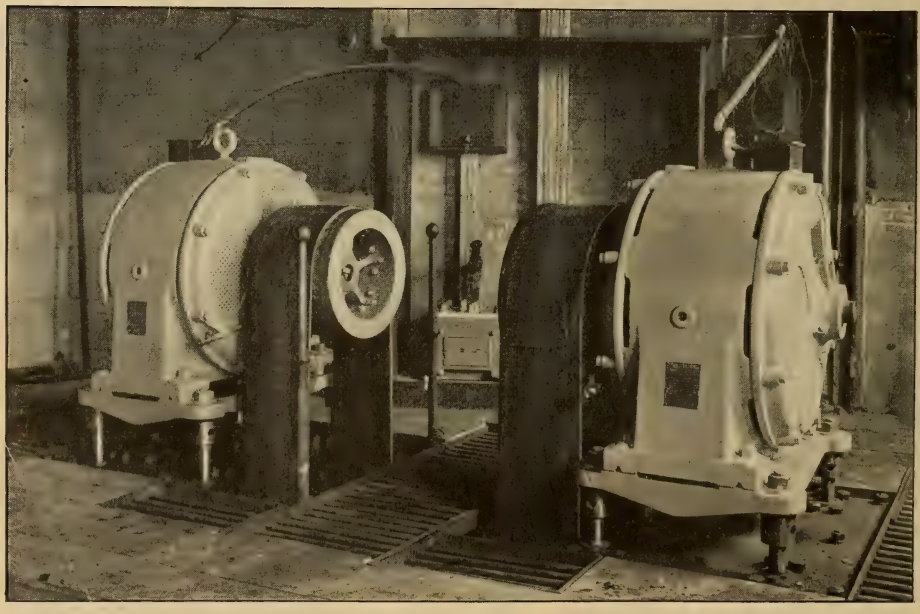


FIG. 31.—WESTINGHOUSE THREE-PHASE INDUCTION MOTORS OF 50 H. P. EACH, DRIVING DRY DOCK PUMPS AT THE YARD OF PALMER'S SHIPBUILDING AND IRON CO., LTD., JARROW-ON-TYNE

dock is pumped out by two centrifugal pumps, each driven by a 50 H. P. Westinghouse three-phase motor, supplied with current from the company's own power station. This installation, which is the largest privately owned power plant in the district among shipyards, supplies both the shipyard and engineering shops of the firm, and consists of two 1000 H. P. triple-expansion marine engines directly coupled to Westinghouse three-phase generators which furnish current at 440 volts. The generators are of the usual standard Westinghouse rotating field type, and are shown in Fig. 22.

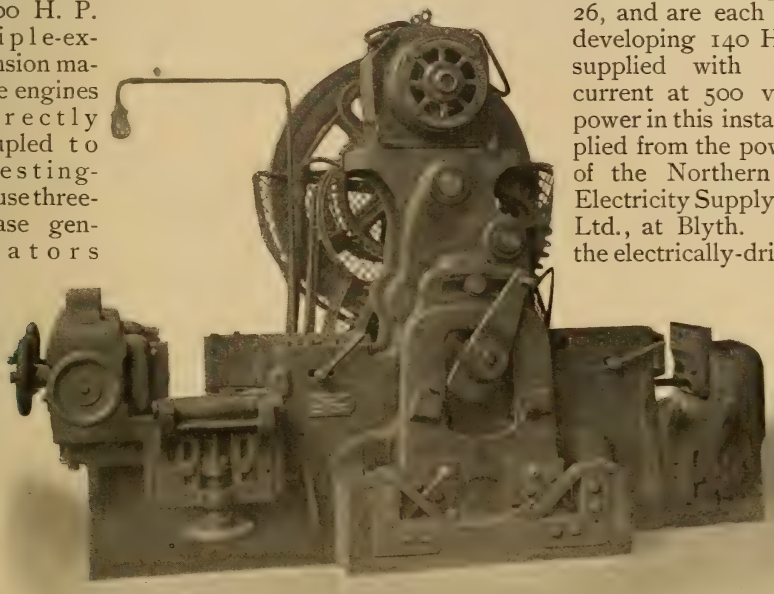


FIG. 32.—ANGLE-IRON BENDING AND SHEARING MACHINE EQUIPPED WITH A 10-H. P. MOTOR BY MESSRS. BRUCE PEEBLES & CO., LTD., EDINBURGH

The motors perform much the same class of work as has already been described. The only feature calling for special mention is the arrangement for starting up the large motors "on load." In this case the current is first of all transformed down on each motor to a lower pressure, so that the 400 volt mains are not suddenly called upon to supply a large current, and as soon as the motor is up to speed the transformer is cut out and the motor is transferred to the mains direct at 400 volts. In this manner a considerable reduction is effected in the fluctuation on the supply mains.

Another example of dry dock pumping is that of a plant which has been installed by Messrs. Scott & Mountain, Ltd., at the Blyth Shipbuilding Company's docks, at Blyth. The motors are shown in Figs. 25 and 26, and are each capable of developing 140 H. P. when supplied with continuous current at 500 volts. The power in this instance is supplied from the power station of the Northern Counties Electricity Supply Company, Ltd., at Blyth. The use of the electrically-driven pumps has demonstrated very clearly that a considerable economy in both the cost of pumping and the time taken to pump out the docks has been effected.

In a descriptive article of this character there is a great deal of matter which is present-day common knowledge, and many articles and papers have been written showing the advantages of electricity over other methods of power distribution; but the aim of this comparatively short and cursory review of the developments on the North-East Coast has been to show how very largely the application of electric power has entered into the operations of the ship-

builder, and how, in a comparatively short space of time, a complete change has been brought about, not only in the manufacturing methods of the shipbuilder, but in the characteristics of his business. There is no doubt that by the aid of electric power he has been able to deal with problems in the construction of ships which would have been more difficult to solve than if the agency of electricity had not been near at hand to help, and it would be difficult to gauge how much the rapid adoption of electric power on the North-East Coast has been responsible for the period of industrial activity which has been in evidence in the district during the past eight or nine years.

It may safely be predicted that at the end of the next decade there will not be a steam engine at work in the district driving a shipyard machine tool, and that electric power will be exclusively employed.

EQUITABLE LABOUR COMPENSATION AND MAXIMUM OUTPUT

By H. L. Gantt

THE fact that to get uniformly the maximum output in manufacturing, a compensation that is satisfactory to the majority of workmen must be awarded, would seem to carry with it the corollary that if an equitable compensation is awarded, the manufacturer has a right to demand the maximum output. The reason why he so often fails to get it is that he has not sufficient knowledge either of what the maximum output or the proper compensation should be. In other words, he does not know what he should get for his money, and it is not surprising that he does not get its full value.

The fixing of the pay for work done is one of the most important operations in modern manufacturing; yet it is one that, in general, has been given the least amount of systematic study. Most establishments have expert financiers, expert designers, expert salesmen, and expert purchasing agents for everything except labour. The buying of labour is generally left to people whose special work is something else, with the result that it is usually done in a manner very unsatisfactory to both the purchaser and the seller. It is admitted to be the hardest problem we have to face in manufacturing to-day, and yet it is considered only when the manager "has time" or has to "take time" on account of the unsatisfactory state of affairs. The time to study this subject is not when labour trouble has commenced and every move, either of the employer or workman, is viewed with suspicion, but when things are running smoothly and when employer and workmen have confidence in one another.

When compensation is fixed for doing work, it should be for doing a definite piece of work with specified implements in a definite way. When the work to be done is accurately known and the implements are provided, it is a matter of investigation to determine the amount that a good man should do, and the writer has yet to find a case in which a pretty accurate solution could not be arrived at if only the proper methods of investigation were followed and the subject given sufficient study. The difficulty is that few people are willing to give the subject the same amount of study that they would give to the design of a complicated piece of machinery; yet it involves more unknown quantities and is quite as difficult of solution. It requires a trained specialist just as much as the design of machinery does.

The fact must be emphasised that the

problem is not an easy one and cannot be solved by men who are busy at something else and work at it only when they have time. Such problems must be studied by capable men who make the solution their main, if not their whole, business. In other words, the rate-fixing expert, if he is not to be a guesser, must be of the same order as the other experts. Then his department, properly administered, becomes quite as important and valuable as the older departments.

The fixing of a piece-rate on the lines just considered consists, then, of two parts,—

1.—A scientific investigation of the amount of labour needed to do the work.

2.—A financial transaction consisting in the purchase of that labour for an equitable compensation.

Of the two, the first is by far the more difficult, as it requires not only a knowledge of the modern methods of investigation, a larger experience in doing work, and an extensive acquaintance with appliances, but the ability to use that knowledge and those appliances to produce new and advantageous combinations. In other words, to obtain the highest type of success in this work a man must be able to devise the best method of doing a piece of work that the appliances will admit of, and, having determined this, to find the amount and quality of labour needed. This done, what remains is simply to buy this labour for an equitable compensation.

The writer lays stress on the word equitable, for the fact that the most successful financial transactions are not those in which one side gets all the benefit, but those that are beneficial alike to the buyer and seller, should eliminate at once the old-fashioned method of rate-fixing by which the foreman and the workman dicker about the price, the former trying to make it as low and the latter as high as possible, with but little regard to the actual amount of labour involved or the method of doing the work. This process of bargaining is still the standard in horse trading and like transactions, but is, to say the least, beneath the dignity of a large manufacturing establishment.

In order to get the information necessary to fix proper piece-rates, much detail work is necessary. When we realise, however, that any operation, no matter how complicated, can be resolved into a series of simple operations, we have grasped the key to the solution of many problems. Further study leads us to the conclusion that many complicated operations are composed of a number of the same simple operations, performed in a different order, and frequently that the number of elementary operations is smaller than the number of complicated operations of which they form the parts. The logical method, therefore, of studying a complicated operation is, undoubtedly, to study the simple operations of which it is composed, a thorough knowledge of which will always throw a great deal of light on the complex operation. In other words, the time needed for performing any complex operation must necessarily depend upon the time and method of performing the simple operations of which it is composed. The natural method, then, of informing ourselves about a complex operation is to study its component elementary operations. Such study divides itself into three parts,—

1.—An analysis of the operation into its elements.

2.—A study of these elements separately.

3.—A synthesis, or putting together the results of our study.

This is recognised at once as simply the ordinary scientific method of procedure when it is desired to make any kind of an investigation, and until this method was known and adopted, science made practically no progress. The writer believes that if it is desired to obtain the correct solution of any problem, we must follow the well-beaten paths of scientific investigation, which alone have led to reliable results. The ordinary man, whether mechanic or labourer, if left to himself, seldom performs any operation in the manner most economical, either of time or labour, and it has been conclusively proven that even on ordinary day work a very decided ad-

vantage can be gained by giving the men instructions as to how to perform the work they are set to do, and, when these instructions are the result of scientific investigation, the gain in efficiency is usually beyond our highest expectations.

Mr. Fred W. Taylor, who was the pioneer in the work of elementary rate-fixing which involves complete detailed instructions, began to work on these lines in 1880, and soon became convinced that they were correct. He has fixed a large number of rates, all of which are lower than those usually paid; but as he takes care to furnish the best implements for doing the work, and insists that the work shall be done as he instructs, the good men always make better wages than they can where they are allowed to work with ordinary implements and in the manner they see fit. His piece-rates, founded on careful investigation, and with an earnest attempt to do justice both to the employer and employee, have produced not only much greater output than any other method in the works where they have been introduced, but a much better feeling among the men towards their employers. The fact that during the past twenty years a great many such rates have been introduced, always with the same result, is a confirmation of the correctness of the principles on which they are based, and leads us to the conclusion that a strict adherence to these principles and a desire on the part of the employers to do substantial justice to their employees would, in a short time, materially lessen the antagonism between employers and employees which seems at present to be so prevalent.

The scientific method of investigation of the elements into which every operation may be divided is the only satisfactory basis for fixing piece-rates, as it is the only method that enables us to fix permanent rates, which alone are satisfactory. To analyse every job and to make out instructions as to how to perform each of the elementary operations requires a great deal of knowledge, much of which is very difficult to acquire; but the results obtained by this method of working are so great that the expenditure to acquire the knowledge is comparatively insignificant.

The difficulty about this method is that the investigation is often long and tedious, for no permanent rate should be set until we know the best method of doing the work, and the exact time that it will take a good man to do it.

For financial reasons it is frequently impossible to wait for a complete scientific investigation of every condition before fixing a rate of pay, and the need of a means of making use of a partially completed scientific investigation, or of what knowledge we have, has long been felt. Piece-work will not do it satisfactorily, for it is not desirable, or even feasible, to change rates frequently, as the workman never feels settled, and is continually afraid of having his wages reduced. This unsettled feeling, which always accompanies the old-fashioned method of rate-setting, is the source of the opposition to that type of piece-work, and the reason why so many men prefer day-work at smaller wages.

An investigation of the laws governing the output of labour reveals the fact that a man who is working at day's wages never does work to his maximum capacity, but will do so if he can be sure of earning a commensurate additional compensation. If the work be light, and does not require much physical effort, this additional amount may be as low as 30 per cent. of his day rate. If, however, the work be hard labour, and he becomes physically tired at the end of the day, he requires 50 per cent. additional to make him put forth all his energies; and if, in addition to the physical strain, the conditions under which the work is done are unpleasant, such as severe heat, he requires 70 or 80 per cent. additional to make him do his best.

These facts, which are well established, enable us to take advantage of the results of a partially completed investigation; for, if we set for a day's work such a task as our investigations prove can be done, and offer for its accomplishment the proper premium or "bonus," in accordance with the facts

just stated, we shall find a very large proportion of men ready and willing to do the work in the manner and time specified in order to earn the increased pay. This is the "bonus system," which was first introduced by the writer in the works of the Bethlehem Steel Company. It consists of teaching an ordinary workman to do a piece of work by the best methods we can devise, and asking him to do it in the time it would take a good workman. If he accomplishes the task in the time set, he is given the wages of the good workman; otherwise he gets simply his own day-rate.* Aside from the educational effect, which is most marked, the result of this is that many ordinary workmen, who lacked only incentive, promptly take their place among those who naturally have more ambition, and the general moral tone is elevated.

When we write out a set of instructions according to the results of a partially completed investigation, the remaining information will, in the long run, generally be found out either by the expert who is making the investigation or by the workman. In the first case, a new set of instructions is made out in accordance with the additional information and the proper bonus is set. In the second case, the same thing should be done; but, in addition, the workman discovering or devising the improved method should be given a cash compensation commensurate with the value of the improvement, which thereafter should belong to his employer. By such a system the workman is encouraged to be something more than a machine, for he is first given the best knowledge available, and paid for learning more. As it is important in any manufacturing establishment to obtain the maximum output from the plant, it is very essential that the maximum product should be secured from every machine, and the fact that a man loses his bonus when he fails to get out this maximum product is a very big factor in accomplishing the desired result, for he learns to take care of his machine or tools, and complains promptly if his work is interfered with.

Again, those who are indirectly connected with the output, such as foremen, men who supply material and appliances, and those who repair machines, all should receive a bonus in proportion to the number of men that produce the maximum output. The whole makes a system that is as nearly automatic as is possible; for what is for the good of one is for the good of all, and a man who will not do his duty soon finds that he is in the wrong place.

This description of the principles on which the bonus system is founded gives but little idea of how it is carried out, but a very little thought shows that proper appliances for doing the work and a complete and exact system of time and record-keeping are the first essentials. Thanks to the recent advances made in the art of doing such work, an exact system of keeping time-records and costs can to-day be made a source of economy by preventing the errors and waste which always go with the methods which depend upon verbal reports and memory.

It has long been the custom to keep a daily record of cash, which must ballance. Modern methods require that we shall keep a daily record of labour and material, and the bonus system in its best development compels a modern system of management in that it requires that we shall at all times know the quantity of work done and to be done, and the means for doing it. Such a system requires that work for men and machines should be laid out as fully as possible the day before, this having a strong tendency to do away with delay and idleness which are expensive alike to the manufacturer and the bonus workman.

That such a system requires more organisation than the ordinary shop possesses is not denied; but few realise how little such organisation costs, and how many times it pays for itself in the course of a year.

The bonus system possesses an advantage over direct piece-work in that

* An exposition of the bonus system was given by Mr. Gantt in a comprehensive article in this magazine for November, 1902.—THE EDITOR.

it is more flexible and can be introduced with greater ease and under conditions where piece-work proper would be impossible. When it is realised that proper piece-work will, in many cases, produce at least three or four times as large an output as ordinary day-work, the difficulties of putting men who have been accustomed to do work in their own way and in their own time directly on piece-work would seem to be, and generally is, extremely difficult. On the other hand, as the bonus is paid to men in addition to their day-rate for performing the work in the manner and time called for by their instruction cards, they do not feel so hostile to the innovation. The instruction cards used with the bonus system do not pretend to represent absolutely the best possible method, but the best method we can devise with the available appliances and the present state of our knowledge, and while they may be changed as our knowledge increases, they are always intended to describe a method which is within the ability of a good man to reach. The difficulty of introducing such a system is far less than that of introducing direct piece-work, for if workmen having their day wages secured to them are given such instruction cards, and a considerable reward is held out to them for doing the work in the manner and time called for on the instruction cards, they will gradually overcome their prejudice against following instructions, and finally attempt to perform some of the operations in the time set. Having performed a few of these operations, and finding out that the card represents a fair and reasonable set of instructions, they will, in a short while, conclude that they might as well have the extra pay, and gradually learn to follow the whole card. This has been the experience of the writer, and he was astonished to find out how quickly the men overcame their prejudice.

The greatest difficulty to be met is to convince the men that these instruction cards are intended to be such as a man familiar with the work can, by due industry and with a fair amount of intelligence, always follow successfully; but when the men are once convinced that this is a fact, and that it is the intention of the company to allow them to earn the reward indicated for the extra work, most of the difficulties are over. To make out such cards requires an amount of knowledge and experience that is seldom the possession of any one man. To obtain this information requires a long series of detail observations and investigations with corresponding records, and even after having obtained a great deal of such information most of the instruction cards will still fall short of perfection. They are intended to represent our best knowledge of how to perform the work, and the man following the card earns his bonus, not because he does the job in the best possible way, but because he does it in the manner which the present state of our information indicates is the best.

If subsequently to having made out a card for a certain job we have obtained more information on that job and find an easier and quicker method of doing the work, our instruction cards may be made to conform to the new and better method; but only such items on the instruction card should be changed as are affected by this new and better method. In other words, no wholesale change in a card is allowable under any conditions. It must be possible always to perform the individual elementary operations in the time set, and when a man complains that he cannot do this, he must be asked to point out the individual operation or operations that he cannot do. If the foreman cannot show him how to perform these operations in the time set, the matter should at once be referred to the man making out the instruction cards, who must either be able to show how to carry out the instructions given or change the instruction card so that it can be followed.

This throws the responsibility for the success of the system on the man making out the instruction cards, who should not only be a good mechanic, but a man of the highest order of intelligence and integrity, for he practically fixes the pay of the men, and is, in a large degree, responsible for the output of the

shop. This is true, whether the instruction cards are made out for a bonus system or for piece-work, and unless a proper man is selected to have charge of this work, the whole system, whether that of paying a bonus or piece-work, will immediately fall into disrepute. Piece-work, when proper piece-rates can be made, is sometimes preferable to a bonus system; but the delay in getting sufficient knowledge to fix permanent piece-rates is often so great that it is absolutely necessary to resort to some shorter method for obtaining an increased output, and the bonus system as outlined here, or some modification of it, based on the instruction cards, is a very efficient means of accomplishing this, and one which is easily introduced because it avoids raising issues with the men.

When the above methods have been properly carried out there has been little or no trouble with the foremen or workmen, but the management has frequently interposed obstacles, the object of which was to prevent a direct comparison of the amount of work done before the installation of the system was begun and that done after these methods were partially installed. In other words, the greatest obstacle in the way of introducing these methods is usually not the workman, but the manager, who may be superintendent or may be president. This is particularly the case in plants manufacturing a variety of machinery, for there the managers are usually doing their work less well than the workmen, and are less inclined to take instruction in the art of management from an outsider, even though he may have made a special study of the subject, while they are scarcely familiar even with the best literature on the subject.

EDISON AND THE INCANDESCENT LAMP

SOME FACTS IN THE HISTORY OF THE LAMP'S COMMERCIAL DEVELOPMENT

WHEN Mr. J. Ricalton returned, in 1889, from a year's exploration tour in foreign climes, made in Edison's behalf in search of a suitable bamboo fibre for electric lamp filaments, he told how he had learned to regard Edison as the most widely known man in the world at that time. In all his journeyings in the Far East he had been astonished many times to find his name so familiar; even the unlettered natives of half-civilised countries had learned to associate it with the electric light.

His donkey boy in the streets of Cairo was endeavouring, in broken English, to tell him something about the Khedive, when Mr. Ricalton asked him the name of the American Khedive. The boy shook his head to indicate that he did not know. Mr. Ricalton mentioned the name Harrison, who at that time was President of the United States, but the boy did not recognise it. Then Mr. Ricalton mentioned Edison's name; the boy smiled cognisantly and drawled the name,—"Ed-ee-sone,"—while pointing to an electric light in front of the hotel. A few weeks later Mr. Ricalton mentioned the name to his courier in Morocco, whereupon the latter quickly proceeded to offer his knowledge of the man.

Edison's name truly, Mr. Ricalton concluded, was a household word even at the ends of the world. What need, therefore, to tell much about him here, to English readers, to most of whom the life of the great inventor has become familiar history.

The portrait of Edison which appears as a frontispiece in this issue is the best one of recent years, and his latest one also, having been taken on the afternoon of February 11, 1904, just prior to the second annual dinner, at New York, of

the American Institute of Electrical Engineers,—an event of special importance in electric history in that it was virtually an Edison dinner, celebrating the twenty-fifth anniversary of the practical perfection and commercial introduction of the electric incandescent lamp, and the fifty-seventh anniversary as well of Mr. Edison's birthday.

In order to further signalise this anniversary celebration of commercial electric lighting, an Edison Medal Association had been formed some months before, made up of a number of old "Edison men," for the purpose of raising a fund necessary for the foundation of an Edison medal which was to be presented every year to the student of any technical school of the United States or Canada who presented the best thesis on some electrical engineering subject, the American Institute of Electrical Engineers acting as trustee. Within a few weeks over $7000 were secured,—more than enough for the purpose in view,—and the Edison Medal will thus henceforth be a coveted prize for the embryo electrical engineer.

With a quarter century of the commercial incandescent lamp just passed, it is interesting to retrace the history of its development, previously given in these pages, and also to go a bit further back to Sir Humphrey Davy's first practical contribution to the science of electric lighting, in 1812, the outcome of which was an electric arc of marvellous brilliancy, 4 inches long, capable of extension to 7 inches when placed in an exhausted receiver and operated by a battery of 2000 cells. The expenses attendant upon the production of this light were so enormous, and the difficulties with which it was interwoven appeared so insuperable, that the principles of the voltaic arc were abandoned until the year 1834, when Professor Dumas, of Paris, revivified them. The enterprise was short-lived, as neither the experimenter nor the French public were in possession of the purse of Fortunatus. Two years later, Daniell introduced a two-fluid battery which tended materially toward the supplying of a steady electric current, and, in 1899, Grove's efforts in the line of electric generators gave renewed life to an art which seemed in danger of entire or partial extinction. In 1844 Foucault's utilisation of carbon from the retorts of gas works was attended by a marked degree of success, resulting from the superior hardness of the material and its greater resistance to heat. The science was now sufficiently matured to be put into practical operation, and the season of 1844-1845 witnessed the illumination of the Place de la Concorde, Paris, by arc light, under the auspices of an enterprising electrician, named Délénil.

This public test was followed by many others, more or less satisfactory in their results; but the most dazzling and fairy-like display was achieved upon the occasion of the coronation of the Czar of Russia, when the utmost resources of the arc light were pressed into service. The capabilities of arc lighting found highest expression in the Jablochkoff candles, the superior attributes of which secured their wide introduction into France and Great Britain. The term candles was derived from the fact that the mechanism of the Jablochkoff system was composed of two cylindrical pencils of compressed carbon, placed side by side, but separated from each other by kaolin, or plaster of Paris. The insulating substance fused with incandescence, and became a conductor at the temperature of the electric arc. The alternating current was used and a flame was thus secured, similar in appearance to that of a wick of a candle.

The excellent properties of the Jablochkoff candles were largely neutralised by one glaring defect. While dispensing with the mechanical contrivances, incident to the regulation of the distances between the points of carbon, for the preservation of the light produced, each candle lasted only a few hours, and this entailed a succession of new burners.

It was this feature of the system which especially attracted Edison's attention, and which caused him to merge his energies into the production of an incandescent solid. Some competitive talent in the principles of incandescent

lighting was already in possession of the field, but neither in quantity nor in quality could it compare with the results achieved by the rival branch. An American named Starr, in the year 1845, patented in Great Britain the first practical application of platinum. In 1847 Dr. Draper, of New York, conducted a series of experiments, based on the qualities of this metal, highly heated. Desprez followed in 1849, with investigations on the subject of sticks of incandescent carbon, immured, in a glass globe, the air of which was exhausted or replaced by nitrogen.

So completely was this transaction lost sight of, and so thoroughly were the modest pretensions of the incandescent solid eclipsed by its formidable rival, that in 1873 the St. Petersburg Academy bestowed a medal upon a certain electrician named Lodyguine, and, later still, letters patent were issued to Messrs. Sawyer & Man for the supposed original discovery of a stick of carbon, made incandescent in nitrogen, the identical experiment made by Desprez in 1849.

It was in the early spring of 1877 that the defects of electric lighting first enlisted Edison's abilities. In the succeeding ten months much was accomplished, and the incandescent light assumed a practical aspect which commended itself to the attention of business men. The outcome of this movement was the incorporation in October, 1878, of the Edison Electric Light Company, with a capital of $300,000 and the following directors and organisers:—President, Dr. Norvin Greene; secretary, Calvin Goddard; Thomas A. Edison, G. P. Lowrey, Tracy R. Edson, James H. Bowker, R. L. Cutting, Jr., G. R. Kent, N. J. Miller, Robert N. Gallaway, G. W. Soren, G. F. Stone, G. S. Hamlin and E. P. Falbri.

On October 16, 1879, Edison decided that he had reached conditions where he thought a carbon filament might be made into a lamp. A cotton thread was the first substance utilised, and a groove in the shape of a hair-pin was cut in a nickel plate, the groove being just wide enough to hold the thread. This was placed in a small nickel mould and filled with charcoal.

Five hours were spent in carbonising and cooking the mould, after which, upon taking the filament out of the groove, it was found to be of such extreme fragility that it promptly fell to pieces, even in such practiced hands as those of Edison's able co-operator, Mr. Charles Bachelor. Repeated experiments were attended by the same disastrous results until a late hour in the night of the 18th, when a filament was rescued intact from its miniature crematory, only to be again fractured in the act of securing it to the conducting wire.

There had been no sleep for the workers since the commencement of the experiment, on October 16, yet so potent was the spell of inspirational genius that Mr. Bachelor at once yielded to Mr. Edison's frantic suggestion that they should make a lamp before they slept, or die in the attempt. On the 19th several filaments were obtained, all of which broke in clamping; but finally, on the morning of the 20th, after many alterations in the clamping devices, a perfect specimen was secured.

In carrying this fragile substance, the focus of so many hopes, from the laboratory to the glass blower building, a malicious zephyr whirled it from its fastening and reduced it to impalpable powder. Utterly unmanned by this misfortune and unhinged by insomnia and fasting, Mr. Bachelor rushed into the presence of his partner and delivered himself of the following despairing sentiment:—

"Edison, it's gone, broken by the wind; I'm sick, I'm disgusted. My impression is, that job got too much reputation on a small capital."

But on the morning of the 21st events assumed a more fortunate guise. A lamp was finally completed, lighted and eagerly watched by the thirty or more experimenters attracted by the unusual interest of the proceedings. Partially relieved by the success of the trial, Edison, Bachelor, and some others took a few hours' sleep, at the end of which time they were greatly elated to find that the lamp was still burning, without

any apparent waste of carbon. This delicate thread of light was anxiously watched for several days, after which Mr. Edison decided to raise the candle-power very high, in order to see how long the carbon would resist the strain. A greater power was attained than the inventor's most audacious dreams had ventured to picture, and sustained through an anxious period of two days; then the soft glow faded, and the tiny filament melted "Like the baseless fabric of a vision." This was the pioneer flame of the Edison incandescent light.

Scarcely had this lamp been burning twenty-four hours before the entire force of laboratory experimenters, fired with the new enterprise, was engaged in carbonising every material which promised to yield the desired residuum of charcoal. Filaments of iridium, platinum and other metals were tested, followed by threads, rubbed with coal tar, plumbago and other substances. Later still, Edison experimented with a horse shoe filament, in which a marked degree of success was obtained, insufficient, however, for the ultimate goal of the inventor's ambition, which looked to the possession of a filament of such inordinate resisting power as to secure a perfect subdivision of the electric light.

In the course of his lucubrations on this subject, a passage of Humboldt suddenly occurred to him, relative to the properties of a certain species of bamboo, growing on the banks of the Amazon. A closer examination of the great naturalist's description convinced him that in vegetable fibres alone could be found the ideal material of which he had been so long in search, and a band of zealous and experienced agents was soon engaged in the work of investigation.

The bamboo which Edison finally selected was discovered shortly afterward in Northern Japan by Mr. William Moore, under whose auspices a tract of land was there purchased and placed under charge of two native farmers. Over $100,000 were expended by Mr. Edison in the course of his investigations, and few portions of the globe were left unexplored.

The structure of the lamps, in the meanwhile, had undergone important modifications. In the fall of 1879 the lamp presented the shape of a nearly globular bulb with an elongated neck, and filaments which extended to the inside of the lamp; the platinum leading-in wires were sealed to the summit of the interior, the tips on the globe were pointed and hollow, and platinum clamps were utilised.

Within the next two or three months the shape of the globe was again altered and its size was enlarged, in deference to the belief that the defective burning power was due to the contracted dimensions of the enclosing chamber. At this point the comparative elimination of air was secured, although the sealing of the glass tops was rough and inefficient.

Later in the spring of 1880 a species of white German glass was utilised at the junction of the platinum wires with the glass, for the purpose of securing a more perfect seal. This was discontinued in the fall of the same year, and the shape of the globe was modified to meet the requirements of the bamboo filaments to which reference has already been made.

In the winter of 1880 the lamp had reached greater durability, the supplemental tips at the summit were shortened, and the platinum leading wires introduced through the glass interior were solidified and rendered more compact by being compressed into shape while hot and malleable. Other lamps, constructed at this period, show novel features, such as the use of a wooden socket,—and the wires coming from the lamp are soldered to contact rings, insulated from each other, one plain and the other threaded to facilitate making contact in the lamp socket.

In January of 1881, tests were made, with a view to substituting the cheaper metals, silver or copper, for the platinum used in the construction of the clamps, and the contact between the carbon filament and the platinum wires was materially improved. Further changes followed in the substitution of plaster of Paris sockets instead of wood, in the heightened resistance of the bam-

boo filament, and the superior symmetry of the general proportions. Between this type and the perfected lamp of the present day, there are fewer points of dissimilarity than between any other of the several forms of evolution. The spring of 1881 gave birth to the first permanent record of electric light, in the shape of an incandescent lamp, which lasted 1589 hours, at a height of sixteen candle-power.

In 1882 the output of incandescent lamps, according to Mr. Joseph B. McCall, president of the Association of Edison Illuminating Companies, amounted to about 100,000. Ten years later the total consumption in the United States was about 4,000,000 per year, and in 1903, practically twenty-one years after the manufacture of incandescent lamps was commenced in commercial quantities, the total consumption in the United States reached about 45,000,000 lamps per annum. It is not many years since, when, in the larger American cities, a connected load of 100,000 sixteen candle-power equivalents was considered a mark to work to, while now it runs up into the millions. There is nowhere a record of commercial results that can compare with this.

NEW AMERICAN WOODWORKING INDUSTRIES

By George Ethelbert Walsh

THE wooded area of the United States has an important relationship to a number of industries which in recent years have developed so that they indirectly touch nearly all sides of American commercial life, and the most recent figures furnished by the United States geological surveys show that American forests are less in danger of complete destruction than is generally supposed. Indeed, these surveys indicate that there is little danger of a lumber famine in the United States within the present life of any living man, and while in some States the wooded area is very small, most of them contain a large acreage of forests. In North Dakota, for instance, the wooded area is only 1 per cent. of the whole area, or about 600 square miles of forests; but Rhode Island, on account of its size, contains only 400 square miles of woodland, although the percentage compared to the total acreage of the State is much higher than 1 per cent.

These two States represent the extreme of woodland scarcity, while many of the others, at the opposite extreme, show very promising conditions. Thus Alabama, with 74 per cent. of the State in woodland, contains over 38,300 square miles of forests, divided up into 18,885 square miles of long-leaf pine, 2307 square miles of short-leaf pine, and 17,108 square miles of hardwoods. Eighty-four per cent. of the total area of Arkansas is composed of woodlands; 79 per cent. of Maine, and about 70 per cent. of Georgia, Florida, West Virginia, and North Carolina.

The almost inexhaustible timber growth of the country has in recent years furnished material for new manufacturing industries which are peculiarly interesting and valuable. These industries are the direct result of attempting to utilise the by-products of the woods, and to the invention of machinery of different kinds. The early destruction of American forests was wasteful in the extreme. The woods were destroyed

to furnish rough lumber for the mills, and the trimmings and small trees and branches were either destroyed by fire or left to decay. In addition to this the great spruce and hemlock forests were considered almost worthless and were frequently burnt over by fires started by careless hunters or lumbermen.

The building of wood pulp mills in Maine and New York for making paper first checked this destructive waste. The spruce woods suddenly assumed an importance in the commercial world that quickly carried them to the front. The improved methods of converting the spruce trees into paper increased the demand for paper until, in spite of scores of mammoth paper mills, it seemed almost impossible to catch up with the ordinary trade demands. The spruce forests were found to be more valuable than any others for paper making, and to preserve these, the large paper companies have pursued a policy of cutting which enables the young trees to grow and mature without injury. Spruce is a slow-growing tree, and it is necessary, therefore, that the spruce forests be protected against unnecessary destruction. It requires from 100 to 150 years for a spruce tree to mature its wood thoroughly, and during the first 50 years of its life it does not reach a very formidable size; in the second half century of its existence, however, its size increases more rapidly, and the last 50 years, while a period of little progress, so far as external appearances are concerned, are important in that the wood is hardening and maturing. A good many of the primeval spruce forests of New England and Canada are in a state of decay, or at least complete standstill, and they will be better for judicious cutting down. Many of the large trees are from 200 to 300 years of age.

Paper making from wood pulp in the United States has grown in ten years from a very small infant industry to one that represents an invested capital of nearly $100,000,000. Probably $150,000,000 worth of paper is manufactured in the country annually, including that made from wood pulp, rags, and straw. This represents between two and three million tons of paper, ranging in price all the way from $20 to $300 per ton retail. The reasons for this remarkable development are the almost unlimited resources of raw material, abundant supply of water-power and cheap fuel, and the invention of labour-saving machinery for converting the raw material into finished products.

The processes of barking the trees, grinding them into a powder, then reducing them to a sticky pulp, and further converting them into merchantable newspaper, are pretty well known, and while new machinery for improving the service is being constantly adopted, the general principles remain nearly the same. The purpose of this article is not to describe such methods of paper making, but to call attention to the utilisation of forest by-products which this pioneer industry indirectly developed.

The waste of the lumber mills was proverbial, and enormous quantities of trimmings were annually destroyed. The remarkable financial success of the wood pulp mills stimulated investigation in other fields. Companies were soon formed to reduce the waste wood of the lumber camps to wood pulp and then compress it into various household articles. A good deal of the inferior grade of wood could thus be utilised for making tubs, pails, dishes, and similar things. Under great hydraulic pressure the wood pulp was formed into a dozen and one commercial articles, ranging from common lead-pencil holders to hollow wood pulp telegraph poles. A great variety of machinery was invented for this trade, and large sums of money were quickly invested in these auxiliary wood pulp mills. Furniture manufacturers created a demand for wood pulp ornaments, which, when stained and decorated, made fairly good imitations of wood carvings; architects found a way to use wood pulp for cornices, dadoes, and friezes; in short, the extent of the demand for wood pulp articles increased to such proportions that the mills were run annually to their full capacity.

The development of veneering machines created a new important industry

in the woods. At first these machines were limited to veneering hardwoods for cabinet purposes; but in time machines were invented for stripping ordinary soft woods into thin sheets for making platters, fruit boxes, baskets, and crates. The remarkable cheapness of these baskets and boxes enables their use on an enormous scale. So extensive is the trade in them that we have ceased to wonder at their appearance. We use them and destroy them without thought of the ingenuity required to invent the machinery for their manufacture. Tens of thousands of pine trees are cut down to feed these veneering machines with material to produce articles which sell at a trifling price. With one stroke of a knife a hundred to five hundred pieces of veneered wood are cut out in the proper size for making a basket, box or crate, with the creases and markings for folding all impressed on them. Enormous folding and riveting machines consume these packages of cut veneers, converting them into finished products with almost human-like precision and delicacy. Thus it is possible to turn out five or ten million finished commercial articles in one establishment in less than a week's time. By such wholesale methods the trade is supplied at a nominal cost with convenient articles for handling fruits, vegetables, butter, and scores of other goods.

Near the great lumber mills of the forests factories have been erected for utilising the waste material of the woods in other ways. Match making has become a perfected institution of modern ingenuity. Millions of cords of wood are eaten up by great hoppers which spout out at the other end bundles of fine wood, cut and squared for immediate use in the match factories. Somewhat similarly allied to this work is the manufacture of toothpicks. Probably a billion or more of wooden toothpicks are used in the United States every year, and these are made from the waste wood of the forests. One Maine factory alone turns out annually nearly half a billion toothpicks besides millions of other forest novelties. The machinery for cutting the matches and toothpicks is simple, and works with the precision and perfection of a printing press. The timber is first veneered and then cut into innumerable small sticks by single strokes of a knife.

The manufacture of wooden spools for winding thread and cotton requires more complicated machinery than the above, but the dozen and a half spool factories in Maine turn out annually over 250,000,000 spools. These are made of white birch timber, which heretofore was considered almost valueless for building or other purposes. About 15,000,000 feet of white birch timber are used every year by these factories, while half as much more is exported to Great Britain to supply the spool factories there with their raw material. Only white birch is used by the spool factories, and as the supply is almost unlimited, it makes this business a permanent industry in the woods. The machinery for turning out the spools on a large scale represents some of the most ingenious yet constructed. The spools are made by a process which enables the owners to utilise the birch timber when comparatively young. The birch trees spring up everywhere, but the softness of the wood makes them easy targets for the wind storms which frequently break them off when half grown.

Another use to which the white birch is put is the manufacture of hoops for barrels, tubs, and kegs. The young birch saplings are employed for this work, and they are cut from the forests of New England by men who are specially engaged for this work. The manufacture of hoops, however, is not conducted on a large scale by factories; it is an industry scattered over a wide area and carried on by a great number of men. From thirty to forty millions of hoops are made in the State of Maine alone. The young birch saplings are cut by hand, and each hoop pole will make two hoops. These poles are cut and stacked near a home shanty for preparing them for the market. Each pole is cut into two hoops by pulling it through a slot where a sharp knife is fixed to split it. Then the worker uses an ordinary draw-knife to shave the

hoops to proper width and thickness. More distinctly entitled to the term of novelties in the woods are the products of a dozen or two mills which make it a business to utilise the waste timber in producing toys, checkers, boxes, and similar articles. These mills are scattered throughout the pine and hardwood forests of New England. They secure their raw material mostly from the lumber mills and work it up into merchantable articles. From ten to twenty million checkers are made in these mills every year, and half as many wooden dice and boxes to hold them. The machinery necessary to manufacture these small articles is ingenious, but not very expensive. The small pieces of timber are turned and then chopped off by machinery in small circular pieces. The boxes are made by a veneering process, the pieces being grooved and dovetailed together. Nearly a quarter of a million dice boxes are thus manufactured in one mill every year. Another article of common manufacture from the waste wood of the forests is the ordinary wooden skewer used by butchers. Tens of millions of these skewers are made every year, and they are shipped by the ton to all parts of the country. Clothes pins are made by a process which enables the manufacturers to utilise ordinarily valueless timber; they are turned and cut out by a machine which makes 50,000 and more a day.

The effort to utilise all the waste wood of the lumber mills has stimulated a class of inventors, connected with these novelty mills, to the production of small machines which will turn out wooden articles of all conceivable kinds. Without adequate machinery there would be little value to this waste material, for the common articles are sold at such small prices that there is no chance for profit unless they can be made by the thousand. Nearly all of the mills manufacture a great variety of articles. Machines for turning out checkers, skewers, toothpicks, and dice boxes are common in the same factory, and there is economy in thus combining different articles. The trimmings and waste from one machine will often serve to supply ample material for another. A large number of factories are engaged in producing a great variety of common furniture articles, such as desks, chairs, tables, and shelves. These are all made by machinery, and are used for ordinary household purposes. There is a great demand for cheap pine tables, chairs and children's desks, and the factories supply the trade with most of these articles. Wheelbarrows, swings, ladders, and stands are also monopolising the attention of some of the larger mills. When the bicycle became an important pleasure article a few years ago the demand for wooden rims was so great that several factories in the forests were engaged in making these rims to the exclusion of all other commercial articles. Special machinery was designed to cut out and finish the rims in rapid succession. But since the decline in the popularity of the bicycle one or two of these factories have turned their attention to other novelties. Some of them have entered into the manufacture of toys on a scale which makes them the most productive of any others in the woods.

The importation of wooden toys from Germany and the Tyrol for the Christmas trade has always been a huge item in the annual expense account of the United States with foreign countries. The toys were made by the poor Swiss peasants, who could carve out by hand and paint them at starvation wages. All members of the households would engage in this work. But in the great woods of New England to-day factories have been equipped with machinery which will turn out in one day more of these toys than fifty households in the Tyrol could produce in a week. The machinery will cut out a hundred animals in one stroke of a huge knife, and the sides of a Noah's ark can be cut out and grooved for fastening together in as short a time. Millions of these wooden toys now come from the Maine woods every year, and they are shipped to every toy store in the country. More than that, they are now being exported, especially to the countries south of the United States. Small toy carts, wheel-

barrows, baby carriages, wooden steam cars and boats, and scores of ordinary articles which please the youthful mind are made by modern machine processes that are not duplicated elsewhere in the world.

All of these products are the result of ingenious application of machinery to the manufacture of the smallest thing which can be made of wood. The factories have built up their trade on the theory that nothing would pay unless it could be made by machinery on a scale sufficiently large to place it within the means of all. The cheapening of the cost of the small wooden objects has naturally multiplied their use tenfold. Millions of common wooden articles are used to-day where thousands were formerly employed. The wooden toothpicks and skewers are considered of no value and are thrown away after serving their one purpose. The grape baskets, berry boxes, and even the wooden crates for peaches and pears are broken up immediately after their contents have been emptied.

It is this regular practice of discarding the articles soon after they have served their purpose that makes it possible for the factories to increase their output annually. The wooden toys of the holidays scarcely survive two months, and they have to be replaced every Christmas or birthday season. By reducing the cost the manufacturers have stimulated an almost unlimited demand, helping to reap profits from waste material which well reward them for their genius and efforts.

Current Topics

It is almost the universal impression that the late Sir Henry Bessemer was knighted in recognition of the steel process which bears his name, but such was not the case. The honour was bestowed in 1878, when he was sixty-six years old, as a tardy reward for a service rendered the British Government about the time of his attaining his majority. The history of this, as told by James Dredge, is that at the time when, in his early years, Bessemer came into contact with some of the officials of Somerset House, the seat of the Inland Revenue Department, it was notorious that frauds on the government were perpetrated to an alarming extent by the repeated use of stamps affixed to deeds. It was estimated that an annual loss of £100,000 was sustained from this cause, and to devise a means for entirely putting a stop to this occupied Bessemer's attention. It is almost superfluous to say that he arrived at a solution by the sim-

plest means, that of perforating the government stamps with dates. Now that this evident method has found a hundred uses throughout the civilised world, to safeguard stamps or cheques, and to divide postage stamps, being among the most common, it is a little difficult to realise the importance of this invention. To Bessemer it meant, in anticipation, vast things,—assured fame, a retaining fee of £600 a year as a government official, and a great advance on the road to fortune. In reality, however, it meant nothing, for though the invention was at once adopted, the official promises were soon forgotten.

THE trend of invention is at present in two different directions, recently remarked Mr. J. Fletcher Moulton, in a presidential address before the Junior Institution of Engineers. On the one hand the tendency is to divide manufacture up into many simple operations, each capable of being performed swiftly and well by a special machine designed solely for that purpose, and thus working under the most favourable circumstances for cheapness of production. Take, for example, the manufacture of machine-made watches. Each machine employed has only a minute operation for its share of the work, several being needed to perfect each piece. But these machines are so nearly automatic that the labour required, for the most part, needs no skill, and the rapidity with which they work makes the actual cost of production almost incredibly small, while the accuracy of the workmanship can be, and is, brought up to a pitch which completely satisfies all requirements of practical use. This tendency to sub-divide the operations of production until they are each capable of being performed either automatically or with unskilled labour, is having momentous effects in labour questions. Strange to say, increase in accuracy of workmanship is tending to increase the demand for unskilled labour. The skill which used to be sought for in the workman is now embodied in the machine. This is due to what Mr. Moulton terms the uniformity of mankind. The chief wants of each class are common to all the individuals that form it. Hence any rise in the standard of comfort of a nation produces a demand for millions of articles of one and the same kind, precisely such a demand as can best be satisfied by the unvarying but economical production of machines of the type here mentioned.

SIDE by side with this tendency toward highly-specialised machines, each doing one small and separate operation, there is the other line of invention, *i. e.*, of machines which combine a whole series of successive operations and turn out a completed article. Here we find, perhaps, the greatest inventive triumphs of our time. Take, for instance, the linotype. Type-setting, type-founding and casting blocks of type as in stereotyping, had all been done by hand, and to some extent had been done mechanically, before the linotype came in. But the new machine united them all in one machine, and enabled an operator, with little greater labour than in working a typewriter, to produce the set-up type, cast in lines ready for printing. It is difficult to say which class of machine is attracting most attention at the present moment,—whether combination or division of operations, synthesis or analysis, is taking the lead. If success is completely attained, the machine that combines in itself the whole series must always gain the day. But the penalty for falling short of perfection is heavier, and the danger greater. Each step brings its own liability to failure, and the failure of a step has more serious and more far-reaching consequences. Yet we have abundant proofs on all sides of us that human ingenuity is equal even to this task.

NO invention, according to Mr. Moulton, can live that does not cheapen production,—that does not lessen the amount of human labour needed to pro-

duce a given result. Thus the ratio,—if we may use such a phrase,—between the results of labour and the labour that produces them is ever increasing with the progress of invention; indeed, we may say that it is directly fixed by invention if we use that word in its broadest sense. But this ratio, which represents the fertility of labour, measures the wealth-producing power of the world. It defines the amount that the individual can contribute to the common store by his own labour, and, conversely, it limits the share which he may hope to receive from that store. We know that too often what a man receives differs widely from what he contributes by his labour. Creation of wealth does not necessarily bring with it distribution. But in this respect invention is on the side of the masses. Production is aided by it only on terms of the uniformity of the article produced. Hence the characteristic effect of invention is to bring within the reach of the many that which previously belonged only to the few. Lace that princes alone could have possessed comes within the means of the moderately rich. Stuffs that only the wealthy could have procured are worn by those who have to earn their daily bread. Thus under the influence of invention products of manufacture become accessible to an ever widening class. And just as invention in the past has responded to the demands of mankind for a higher standard of comfort, so it stands ready to respond to whatever such calls are made on it in the future.

As one of the most direct evidences that wrought iron possesses some advantages over steel, Mr. Archibald P. Head, in a recent address on "Metallurgy as Applied in Engineering" before the students of the Institution of Civil Engineers, mentioned the existence at the present time of a considerable wrought iron industry, and the fact also that iron plates, for example, are selling at a higher price than steel plates, being, therefore, presumably worth more to the purchaser. Wrought iron is less subject to corrosion than mild steel, because the fibres are separated from one another by slag, which forms a most efficient protection. It is, in fact, as Mr. Head puts it, painted throughout. Mild steel has no such natural protection, and the deterioration of steel when exposed to alternate moisture and dryness is rapid. According to a prominent bridge builder, most of the bridges supplied by his firm for London or the district for twenty miles around are specified by the purchasers to be of wrought iron so as to resist the ravages of corrosion, which are especially serious owing to the fogs. Painting, unless frequently done, cannot be relied on as a protection from corrosion. In any case, it is expensive, and is difficult to supervise. Possibly pneumatic painting or spraying may be perfected to such an extent as to make the question of corrosion of minor importance. Again, the homogeneous and granular structure of mild steel renders it liable to crack in a way which, during its earlier history, was looked upon as mysterious. A small crack in the edge of a plate is liable to extend rapidly and suddenly, especially if the thermal treatment had been such as to set up internal stresses. The crack is, in fact, a tear, and leaves the torn edges of undiminished thickness. Wrought iron, on the other hand, being of fibrous structure, resists such tearing action, each fibre interposing an obstacle in the way of its extension. A parallel case can be observed in textile fabrics, where materials of a fine texture tear more readily than those of a coarse mesh.

STEEL castings, on the other hand, are rapidly coming into favour for some engineering purposes to replace iron castings. They are stronger, weight for weight, and less brittle, generally giving warning of distress by bending. There is, however, still much room for improvement in their manufacture. Surface blow-holes are very frequently seen, being not only unsightly, but leaving a doubt as to how much the

same sponginess may exist in the interior of the casting. Again, the necessity of annealing renders steel castings expensive. But even if the technique of producing steel castings had reached perfection, there are still many advantages possessed by iron castings which are likely to ensure for them continued use. Owing to the lower temperature of cast iron, and the absence of destructive effect on the lining of the mould, the casting takes the form with great exactness. Intricate or ornamental castings are, therefore, best made of iron. Again, iron castings are much cheaper than steel, and much more rapidly made,—a fact which is of paramount importance in case of a breakdown, and which will often weigh the balance in their favour.

UNDER the head "Metallography" in the same address, Mr. Head said that if samples of iron or steel are chemically analysed, they are found to contain definite quantities of metals and metalloids. At one time this was supposed to be a complete indication of the nature of the material. There are, however, factors other than chemical analysis which have an important bearing on the subject, namely, the form in which the constituent substances occur as revealed by the microscope. One has only to call to mind the tempering of tools to see the importance of heat treatment on the nature of steel, quite apart from chemical composition. This subject is being investigated simultaneously by an enthusiastic band of workers, and already important results have been achieved. If iron or steel are polished, etched, and examined microscopically, they are found to consist of conglomerates of minute particles of different substances in varying proportions. The chief of these are,—1. Ferrite, or pure iron, being soft, ductile, and of high conductivity. 2. Cementite, or Fe_3C., —a definite carbide of iron, harder than glass and very brittle. 3. Pearlite, or a mixture of six parts by weight of ferrite to one of cementite. 4. Martensite, or a solid solution of carbon in iron, containing from traces up to 1.1 per cent. of carbon,—a hard, brittle substance, varying in these characteristics with the amount of carbon. Martensite is the chief constituent in suddenly cooled and hardened steel. 5. Austenite, which is obtained by quenching steel containing from 1.1 per cent. to 1.6 per cent. of carbon, from 1000 deg. Cent. in ice brine. It is not so hard as martensite, can be machined, and is non-magnetic. 6. Graphite, or carbon, —found in slowly-cooled cast iron. Troostite and sorbite occupy intermediate stages between martensite on the one hand, and pearlite on the other.

ORDINARY wrought iron and mild steel consist of a mixture of ferrite and cementite, the softer steels,—such as those for rivets, ships, and structural work,—being about 99 per cent. ferrite and 1 per cent. cementite; while the harder steels,—such as those for rails designed to resist abrasion,—may contain 93 per cent. of ferrite and 7 per cent. of cementite. The carbon contents may be ascertained by dividing the percentage of cementite by 15. As the cementite increases, the hardness increases and the ductility diminishes without apparent limit. The tensile strength increases till the cementite reaches 15 per cent., above which it falls off. Grey cast iron, which is so much used in foundries, consists of a mixture of ferrite or pearlite as a matrix through which is scattered graphite, rendering the mass weak and brittle. White cast iron differs from steel only in a degree, being a mixture of ferrite and cementite, the latter rising in some cases to 67 per cent. High-carbon tool steels, hardened by quenching, consist almost entirely of martensite. The same steel cooled slowly consists of pearlite, and is sometimes free ferrite or cementite. Cutting-tools contain from 0.75 to 2 per cent. of carbon, the latter percentage approaching the boundary between steel and cast iron. Heat affects steel by altering the condition of carbon; hence, the greater the percent-

age of carbon, the more fusible the steel and the more easily burnt, burning being incipient fusion. The mere mention of these facts must be sufficient to show their immense importance; and as our knowledge of the microscopic structure of iron and steel increases, the practical application of that knowledge will find a place.

THE recent collapse of a tall hotel structure in course of erection in the city of New York is only one of a long list of building wrecks of which the precise origin will probably never be known. The fact, however, that cast iron entered largely into the make-up of the frame of the building in the shape of columns, prompts *The Engineering Record* to say that such wrecks should bring home to building owners and to the building departments of cities the question of permitting cast iron columns to be used at all. Extended experience with wrought iron and steel columns indicates with reasonable certainty that under ordinary good design such wrecks would be impossible with them, as the defects characterising a brittle metal like cast iron would be entirely avoided. It is a fact, moreover, that, in tall buildings at least, cast iron columns of equal strength with those of steel yield no economy whatever over a well-designed steel frame. While some economy is claimed for cast iron in low buildings, it can at most amount to but little, and may be imaginary. The question arises, then, whether the time has not come for cast iron columns to be relegated to disuse in buildings precisely as they have been excluded from bridge work for a quarter of a century. However much may be said in their favour, the broad question still asserts itself:—Is it worth while to imperil life and property by the use of a class of members that have failed repeatedly and are likely to fail at any time in the future, when all such danger may be eliminated by the use of a stronger and more ductile material possessing better qualities of every kind without exception, and which can be used with equal economy? Good business and a proper regard for past experience indicates that municipal building departments should take the position which engineers assumed so many years ago, and have never regretted.

TALL iron and steel frame buildings, *The Engineering Record* continues, have been constructed in considerable numbers annually for a period of fifteen or twenty years. During this period there has not been one known instance in which a wrought iron or steel frame has collapsed either before or after completion, excluding those cases, if there be any, in which defective foundations have produced failure. On the other hand, whether the fact is with or without significance, a number of buildings with cast iron columns have failed and have produced building disasters of no ordinary magnitude, involving not only loss of property, but large loss of life. It is not the purpose of this comment upon building failures to make any sweeping condemnation of properly designed cast iron columns, but the facts as they stand should be recognised. Whether those facts are of such a character as to teach a lesson in the design of iron buildings must rest largely with the individual judgment of parties in interest, but an engineering consideration of such a question compels a recognition of the situation as it is. One of the great merits of the production of steel members is found in the fact that the quality of metal is under complete control in all stages of manufacture from the furnace up to the shipment of completed members. On the other hand, the unreliable character of cast iron as a structural metal has been so well known that engineers have excluded cast iron columns from all bridge construction whatever for more than twenty-five years. It has been perfectly well known that castings from the grades of cast iron ordinarily used for engineering purposes are liable to be affected in all parts by blow-holes, cinder spots and other defects, seriously impairing their carrying capacity and safety. It mat-

ters little how many drill holes may be made in a cast iron column to determine the thickness of the metal or its character. Such holes may show satisfactory results in every particular, while alongside of any one of them there may be such a defect as to make the column unfit for use, and that sort of thing may be found at almost any number of points. When these defects are liable to take place not only in the body of the column, but also in the brackets and other details, the hazardous character of cast iron members of this class may easily be realised. There are, it is true, many buildings with cast iron columns that have stood with an apparent satisfactory performance of duties for many years; but there is no reasonable ground for supposing that even such cast iron columns are carrying their loads with anything like the factor of safety that nominally belongs to them. Indeed, the latest and most extensive series of full-size column tests shows that the formula commonly used has greatly over-estimated the carrying capacity of cast iron columns. When this fact is coupled with the certainty of defective and weakened spots in columns and their details, there can be little satisfaction in contemplating what margin of safety may exist.

SINCE the recent great Baltimore fire exaggerated ideas have prevailed as to the demand for structural steel which may result from the rebuilding of the burned district. Commenting on the many daily newspaper articles pertaining to the fire which have appeared, and in nearly all of which reference has been made to the advantages likely to accrue to the American steel trade from the enormous consumption of steel in the replacement of the burned business structures, *The Iron Age* recently said: —"One would infer from these statements that an extraordinary amount of steel would be required,—say, for instance, hundreds of thousands of tons. The consumption would certainly have to run up to figures of this kind to justify the expectation of the great advantages to be realised from this source. It is, however, quite in line with the incorrect idea generally prevailing that the use of steel in building work has been of very great benefit to the steel trade. The increase in the number of buildings in which steel framework is used has, it is true, been very great in recent years, and public attention is naturally turned in this direction. When people see an imposing building, running up to twenty or more stories, and are told that it is a steel structure, they assume that it is almost wholly composed of steel, and that it has consequently taken a huge tonnage. They are, therefore, quite surprised when they learn that a very large building can be put up with steel framework which will not involve more than 3000 or 4000 tons in its erection. It is an exceptionally large building which will require as much as 10,000 tons.

"THE consumption of steel in building work," further says *The Iron Age*, "can probably be best comprehended by taking the statistics of steel production in the leading lines. The figures for 1902 are the latest available. According to the statistics of the American Iron and Steel Association, the production in the United States of structural shapes in that year was 1,300,326 gross tons. It must be understood in this connection that the term structural shapes covers not only such shapes as are used in buildings, but other structural forms for use in bridge work, steel cars, shipbuilding, tunnel work and for a number of other purposes. It is probable that less than half of this output actually went into the construction of buildings. The total tonnage, however, was under that of the output of other leading steel products in that year. Wire rods, for instance, which are the foundation of the wire industry, ran up to 1,574,293 tons. Ordinarily the public would be disposed to believe that much more steel would be used in the erection of imposing buildings than in such insignificant forms as wire nails and other wire goods. The tonnage of

plates and sheets was double that of structural shapes, having been 2,665,409 tons. Bessemer steel rails much more than doubled structural shapes, the quantity turned out having been 2,935,392 tons. The tonnage of miscellaneous rolled products, such as bars, skelp, hoops, etc., was 5,468,696 tons. These figures show that the popular conception of the importance of the structural trade is wide of the truth. The burned district of Baltimore will, of course, not be wholly replaced with steel structures. This would be highly improbable. If the quantity of structural steel used in Baltimore buildings within the next six months should run over 50,000 tons, it will be surprising."

ACCORDING to Mr. E. W. Parker's final report on the production of coal in the United States in the calendar year 1902, just published by the Division of Mining and Mineral Resources of the United States Geological Survey, the total production of Pennsylvania anthracite coal was 36,940,710 gross tons, and the total production of bituminous coal in the whole country in the same year was 232,336,468 gross tons. The report gives the total production of coal in the United States in 1902 as amounting to 269,277,178 gross tons. The production of Pennsylvania anthracite coal in 1901 was 60,242,560 gross tons, and the total production of bituminous coal in 1901 was 201,632,276 gross tons. The total production of coal in 1901 was, therefore, 261,874,836 gross tons, or 7,402,342 tons less than in 1902.

AMONG the many new uses which have opened up for concrete in recent years is its moulding into railway ties, of which Consul-General John K. Gowdy, at Paris, writes in a recent report. On all railways in French colonies near the tropics the ties, he points out, are generally of iron, timber being destroyed in a very short time by the climate or insects. In Cochin China iron is used exclusively. In West Africa a very hard native wood is occasionally employed. Four or five years ago M. Sarda, a cement manufacturer at Perpignan, in the south of France, proposed the use of concrete ties, and sent a few samples to the minister of the colonies; but, after a careful examination, the engineers of the Public Works Department reported that they were unsuitable on account of the cost, size, and extra weight. They were also of the opinion that concrete ties were best suited to lines where the traffic was heavy and where frequent express trains ran, whereas on colonial railways the traffic is light and all the trains are slow. The ties, however, were satisfactory as far as strength, endurance, and immunity from damage by climatic changes and attacks by insects were concerned, and might be employed if they could be manufactured on the spot in any of the French colonies.

HAVING failed to get his concrete ties adopted by the minister of the colonies, M. Sarda applied to the State Railway in France, and in March, 1900, submitted four as samples. They were not made entirely of concrete, but what the French call "ciment armé,"—iron and cement combined. The skeleton consisted of five metal plates, placed vertically and held in position by stout iron wire or thin bars. The interstices were filled with cement. A thin layer of compressed felt, about one-fifth of an inch thick, was put between the tie and rail. These four ties were placed on the line near a small depot, about twelve miles from Bordeaux, in October, 1900. A year or more later the track overseers reported that no fault could be found with them, but it was impossible to judge from tests on such a small scale. The maker was, therefore, requested to make the number up to 100. These were duly received and laid down between April 20 and July 1, 1902. The length of line on which concrete ties are at present used is less than 100 yards. The ties are rectangular, with rounded

corners and slightly thicker where the rail chairs are placed; the average thickness is about 4 inches. The weight of each tie is about 308 pounds, and the cost, 14 to 15 francs. The only means used to reduce shock is the thin layer of compressed felt previously referred to. It should be mentioned that superficial cracks were noticed in thirty of the 100 ties when they were laid down; but these cracks do not seem to have spread, for no complaints have been received from the track overseers. The experiment is too recent to enable any definite opinion to be formed, for the usual life of a timber tie in France is about fifteen years, and, therefore, considerable time must elapse before comparison can be made as to whether cement is superior to timber in its power to resist shock, atmospheric changes, replacement of chairs and bolts, wear and tear, etc. At present it is impossible to say whether any economy would be effected in track labour or material; but, in the opinion of the chief engineer of the State Railway, this is not probable unless the cost of the ties can be considerably reduced. The price now charged is considered to be a serious obstacle to their employment, whatever their advantage may ultimately prove to be.

Since the commercial introduction of aluminium an important problem has been the discovery of means for hardening the material so that it might enter into uses which the softness of the pure metal precludes. It is now claimed, according to *The Electrical World*, that a discovery of such a means has recently been made by W. Rubel, of Germany, the process of hardening being a chemical one. The new metal is called "meteorit," and is claimed to retain all the good qualities of pure aluminium and possess important new ones. The specific gravity is practically equal to that of aluminium; the metal is not affected by acids, the atmosphere or sea water; it can be cast like iron, has 8 per cent. greater tensile strength than cast iron, and can be recast without losing its qualities. It can be rolled cold, and does not become brittle when hot; it has nearly the conductivity of copper, will keep a high polish, and can be plated.

Nearly all parts of China, so Consul Gracey, of Fuchau, tells us, are greatly in need of better facilities for supplying the people with pure drinking water. In all the city of Fuchau, for example, with its million of people, there is not a single pump, windlass, or other mechanical appliance for raising water from wells or bringing it from the river to supply the city. Every householder brings his own pail and rope by which it may be lowered into the well, and, when supplied, carries both away with him, so that a traveller must be the recipient of his hospitality or go without a drink. If the supply is brought from the river it is carried on men's shoulders, two pails being suspended from a bamboo carrying pole. There is no public water system in all Southern China.

The screw propeller question, according to *The Engineer*, of London, seems to be in much the same position as it was left by Griffiths more than thirty years ago. Mathematicians and towing tanks together have entirely failed to produce any consistent information as to what really does take place when a screw is employed to propel a ship. Theory after theory, explanation after explanation of screw propellers is provided by earnest, thoughtful men, and yet ships still go to sea which waste thousands of horse-power, and no one is the wiser. A new propeller is fitted, and the results take everyone by surprise, and no one has any connected ideas as to why and how the last propeller comes to be better than the first. Out of all the confusion the most that can be expected are a few general facts, and the relations even of these to each other are not understood.

Manufacturing News

THE Lagonda Manufacturing Company, of Springfield, Ohio, are putting on the market two kinds of boiler tube cleaners, one of them being known as the "Mechanical" and the other as the "Water Power" cleaner. The former is provided with the form of cutter head shown in Fig. 1. This is used when the scale has almost closed the tube, the augur-shaped cutter in advance preparing the way for the following cutters.

Boiler Tube Cleaners

For removing the scale usually found the forward and second heads are used without the augur-shaped cutter. The forward head has four hard, iron, serrated, cone-shaped cutters, each of which revolves independently of the other, and all of which revolve with the machine as it is driven by the belt. This head is used where scale is very heavy and hard, and is effective in the heaviest scale usually found.

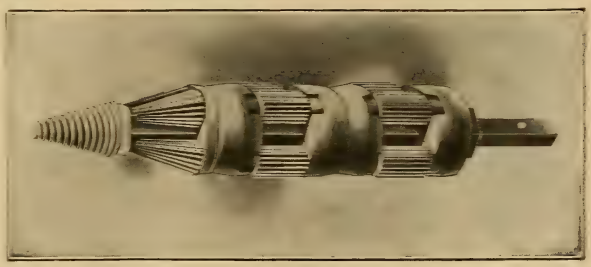


FIG. 1.—CUTTER HEAD FOR MECHANICAL TUBE CLEANER. MADE BY THE LAGONDA MANUFACTURING COMPANY, SPRINGFIELD, OHIO

The second head has a forged steel shaft on which is placed four forged steel discs. The cutters on this head also have serrated cutters made exceedingly hard, and, having ample stock, are very strong and durable. These cutters have steel shafts or pins, the ends of which work in forged steel blocks which are placed in the jaws of the steel discs. These blocks move freely in the jaws, allowing ample movement of the cutters, which thus, when in operation, adjust themselves to the scale and gradually but effectually remove it.

The machine is strongly built in every part, and, it is claimed, very durable. The cutters are the only wearing parts, and they can be replaced at small cost.

The cleaner heads, with cutters, are attached to one end of a rod or shaft. A handle is attached to the other end, which is held by the operator, who allows the cutters to work down into

the tubes as fast as the scale is removed. The shaft works in a sleeve which passes through the opening in the manifold in front of each tube. This sleeve is of the same diameter as the tube, the end setting flush against it. A turn-buckle with hooks at both ends has one end attached to the sleeve, the other to the manifold directly above, or at either side of the tube being cleaned. This turn-buckle is tightened when the sleeve is in place and holds it firmly in position. It can be quickly loosened and the sleeve and cleaner removed when the work on the tube is finished. The cleaner heads with the cutters remain in this sleeve until work commences, when they are pushed into the tubes as fast as the scale is removed, and they are drawn back into the sleeve again when changing from one tube to another.

The cleaner is operated by a belt, driven by any suitable power, the belt running from the driving pulley over flange idler pulleys to the cleaner. These idler pulleys are placed on the lower end of a freely-swinging board attached at the other end to the sleeve. The belt, when in operation, is held perfectly tight by drawing the lower end of the board away from the power, and is quickly loosened when the machine is not in motion, and when changing from one tube to another, or one row of tubes to another.

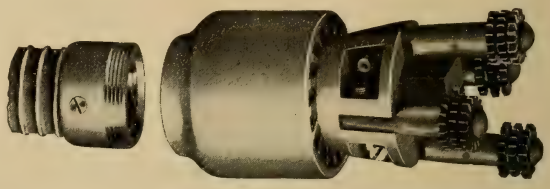


FIG. 3.—WATER POWER OR TURBINE TUBE CLEANER

From 5 to 8 horse-power, according to conditions, it is said, will operate the cleaner. In Fig. 2 the power is provided by a small electric motor.

The Water Power cleaner can be connected to a water supply by means of ordinary hose and suitable couplings attached to the threaded end of the machine. When ready for use the cleaner is inserted in the tube to be cleaned and the water turned on, its force being applied directly to buckets arranged on the plan of a turbine water-wheel, which causes the machine to revolve at a very high speed and with such force that the cutters shatter and remove the scale. The water escapes through the buckets and flows on through the tube, carrying the loosened scale with it.

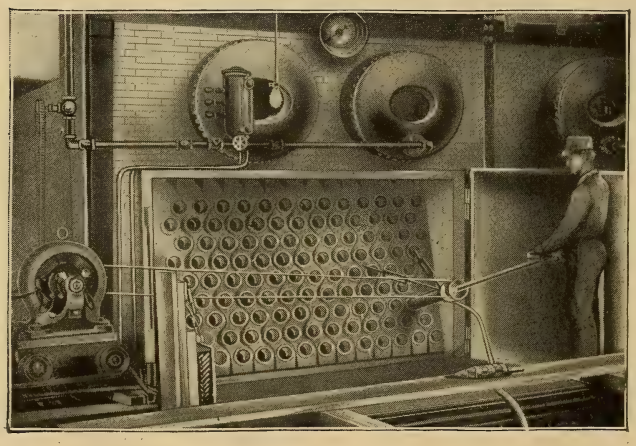


FIG. 2.—MECHANICAL TUBE CLEANER OPERATED BY A SMALL ELECTRIC MOTOR

The machines are generally equipped with one star and one cone-shaped cutter on two of the arms and three star cutters on the other two, as shown in Fig. 3; but with very heavy scale it is advisable to use cone cutters on all of the arms. These arms are pivoted or hinged to the water-wheel, and the centrifugal force keeps them in contact with the scale, allowing them to adjust themselves to any unevenness, the cutters thus doing most effective service without injury to the tubes. Provision is

made for taking up any wear or lost motion in the parts, and adjustment is quickly made without taking the machine apart. It is made from hardened malleable iron and steel, all wearing parts thoroughly hardened and interchangeable, and care being used to produce a strong, durable machine.

A Large Injector Record

RECENTLY the Penberthy Injector Company, of Detroit, Mich., placed the number 300,000 on one of their "Penberthy" automatic injectors, having completed this number of injectors in just a little over sixteen years. They rightly consider that this is a most remarkable record, especially when it is taken into account that it took nearly ten years of hard work to convince engineers that an automatic injector was a practical device, and to manufacture and sell the first 100,000 machines. It is somewhat difficult to comprehend what is meant by 300,000 injectors. Possibly the following facts may help to an understanding of the subject. Basing the figures on the average capacity of the injectors sold during the past twelve months, the 300,000 "Penberthy" automatic injectors on the market will handle in one hour 109,500,000 gallons of water. This amount of water, if pumped into an upright tank 50 feet square, would require the tank to be over a mile high; or, to put it in another way, if the output of these 300,000 injectors were combined into one stream, they would supply a river 10 feet deep and 250 feet wide, and keep up a steady flow of water at the rate of a little over one mile per hour. If the 300,000 injectors were all connected to one source of water supply, they would in ten hours completely drain a lake 10 feet deep, one mile long and half a mile wide. The "Penberthy" injector is acknowledged as the standard among automatic machines everywhere and has never been surpassed in its working qualities by any injector retaining the automatic feature until the same company placed on the market a few years ago their auto-positive, hot water, high pressure, restarting injector, information regarding which they will be glad to furnish any inquirer.

A Story of Expansion

WHILE rapid growth is the rule rather than the exception of the day, there are certain enterprises which command special note by reason of the elements which have contributed to their success. As an example of remarkable expansion directly traceable to high principle and well-studied method nothing could be more interesting than the career of The Sherwin-Williams Company, of Cleveland, Ohio, the large paint and varnish makers.

First-quality goods, perfect system, extensive advertising, co-operation,—these strike the keynote of the firm's growth. These things have been made a science, with the result that from occupying a small one-story building at Cleveland the company has come to own and operate the largest system of paint and varnish factories in the world. And the rate of expansion is by no means on the wane. The company's four plants at Cleveland, Chicago, Montreal and Newark have all been greatly enlarged of late years, the capacity of those at Montreal and Newark having been more than doubled within a twelve-month. Distributing facilities also have been steadily broadened, until to-day Sherwin-Williams branches are located in fourteen cities.

Not only is the company conspicuous in the broader fields of the paint industry. Extensive research and experiment have been conducted in the interest of trade specialties. Important among the paints and varnishes thus produced are superior lines for the use of engineers and makers of machinery. These include coverings, protective and otherwise, for every kind of construction work, from the most delicate piece of electrical mechanism to the heaviest farm machinery and structural framework. Every product is designed with a perfect knowledge of its requirements, and

is manufactured with consummate skill, aided by the most approved appliances.

Everything touching the paint industry has been brought within the scope of the company's study. The firm makes its own tin cans and boxes; it designs its own machinery and buildings; it maintains its own laboratories for the analysis of material; it conducts its own advertising department, with staffs of editors and artists, and it operates its own presses and bindery.

The methods of The Sherwin-Williams Company and the thoroughness with which they have been pursued are the secret of its growth.

New Trade Catalogues

"TOOLS" is the expressive name of a catalogue recently published by Messrs. Hammacher, Schlemmer & Co., hardware dealers, of New York City. The title of the book is no broader than its contents, as tools for machinists, metal-workers, carpenters, cabinetmakers, woodworkers, wood-carvers, pattern-makers, jewelers, plumbers, gas-fitters, upholsterers, sculptors, masons, stone-cutters, moulders, modelers, painters, and paper-hangers are listed. Outfits for manual training and technical schools, and smaller ones for the amateur and Jack-of-all-trades, are embodied in this book. Price lists of the various tools also are given. The book comprises about 8co pages, and is neatly bound in red and gold.

A catalogue exceptionally attractive in arrangement and execution is that issued by the Broderick & Bascom Rope Company, of St. Louis, Mo. It is, in point of fact, a little treatise on underground wire rope haulage, with special reference to the tail rope system as applied in the workings of the Coal Valley Mining Company, at Sherrard and Cable, Ill. Besides attractively illustrated descriptions of the plants in question, the catalogue gives an interesting summary of the cost of equipment and maintenance of a mine, both with mule and wire rope haulage. It further gives illustrations and particulars of what is known as the Frazier mine car coupling.

A new catalogue of rock drills, mining and quarrying machinery has just been issued by the Ingersoll-Sergeant Drill Company, of New York. The economy of rock drills is discussed, and statements of cost of operation, obtained from users of the drills in various lines, are presented. Besides descriptions of the machines and their parts, together with special automatic appliances, which are given, pictures are shown of the drills in service in many places.

The American Diesel Engine Company, of New York City, has distributed a pamphlet on the economy of the Diesel oil engine. The subject is presented in a convincing manner, and many tables are given which show the economy of the engine in dollars and cents as compared with other sources of motive power under varying conditions. The different forms of the engine made by the company are illustrated, and tables give the principal sizes in which they are manufactured. A description of the engine and its parts completes the pamphlet.

A well-illustrated pamphlet has been issued by the Yale & Towne Manufacturing Company, of New York, showing the various uses to which their triplex block is put. Numerous shops in which power is unavailable or costly find the triplex block, suspended from overhead trolleys, adequate for their purposes.

Manufacturing News

INDUSTRIAL RAILWAYS

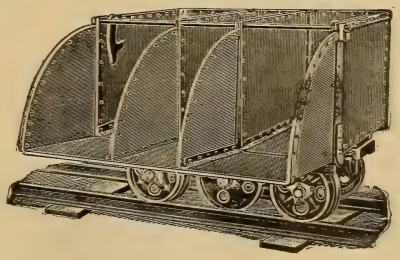
By Ernst Wiener

INDUSTRIAL enterprises, as the writer understands them, embrace shipping, milling, mining, building, contracting, lumbering, agriculture, etc. In all these enterprises one of the main problems is the question of handling materials from beginning to end, regardless as to whether it be the raw material, the material while in course of manufacture, the finished product, or whether it is material for auxiliary purposes, as, for instance, coal, cinders, ashes; or waste, such as scraps, shavings, etc., or any of the thousand and one things which have to be handled in connection with the industrial operations.

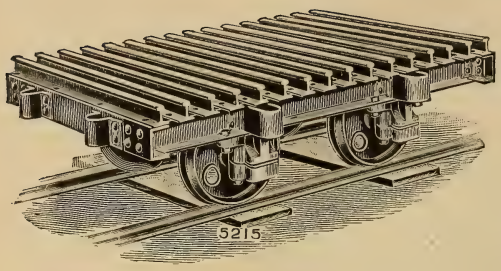
To this question should be given the most careful study and attention, as it is really one of the greatest importance, and one upon which very often depend, if not entirely, at least to a very great extent, the life and success of the enterprise itself.

The man who knows how to handle his material in the quickest and cheapest way is always ahead of the one who has not studied this matter, for the reason that the finished product costs him less, and he gets just as much for it as the other man who is not as well equipped.

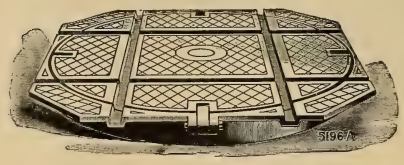
The money thus saved is pure profit and makes the concern a stronger one, as just by such profits net earnings are increased or sales prices can be reduced. What this means everyone knows, and it certainly should not be forgotten just now, at a moment when business is slacking up and sales prices have to be reduced as much as possible in order to get orders. Under any and all conditions the firm that handles its goods



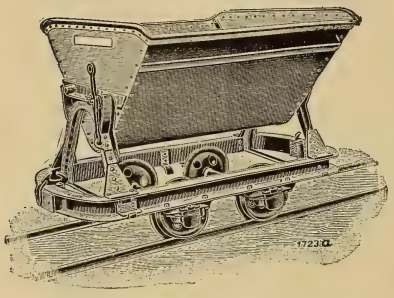
CHARGING CAR WITH THREE COMPARTMENTS. THIS CAR IS EQUIPPED WITH SIX WHEELS, FOUR FOR RUNNING ON TRACK AND TWO FOR SWINGING THE CAR ON THE FLOOR IN LIMITED SPACE



A CAR FOR CARRYING HOT INGOTS AND BILLETS



A SMALL TURNTABLE FOR INDUSTRIAL TRACK, FLUSH WITH THE FLOOR



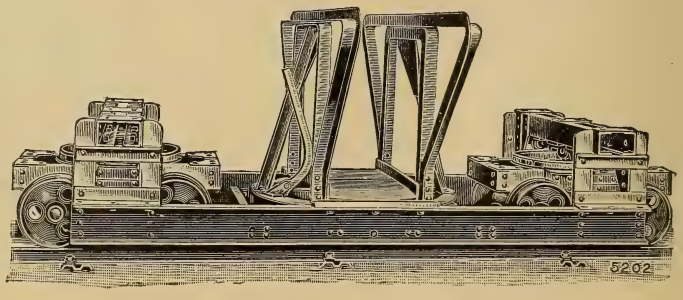
STANDARD STEEL DUMP CAR FOR COAL, ASHES, CINDERS, SAND, ETC.

with the least possible expenditure of time and money, will be the one to pass through trying periods, and will still do business when others succumb. This is especially true nowadays, when competition is so very sharp that every cent that is saved counts, and a few cents saved per ton will make a very handsome total at the end of a year.

The writer will now proceed to show how the saving can be accomplished and how the material can be handled quickly, economically, safely and systematically. The means to which he wishes to refer are small railways of narrow gauges of, say, 20 or 24 inches.

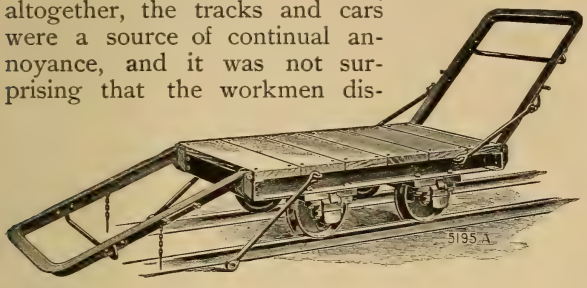
Up to a very few years ago these railways were practically unknown. Some people, of course, had a vague idea that something in this line would greatly help them in lessening expenses and facilitating the handling of their material. They proceeded, therefore, to buy somewhere, probably from the railroad which passed near them, some old rails, without paying any attention to their weight, size or height. They simply took what they could get, and did not get what they required. These rails were attached to some kind of timber or old railroad ties. The users made the cars themselves, partly or entirely, or had them made by someone who, of course, did the best he knew how, but who did not pay any particular attention to the looks, quality, or the purpose for which they were intended.

The result of all this was that the so-called "railroad" did not work satisfactorily; the heavy and clumsy cars could not be moved by one or two men, would not pass through all of the alleys or doorways, nor go around curves; they would be too narrow for one class of goods and not wide enough for another, would be too low for one place and too high for another. Perhaps they would not even stay on the tracks, as the gauge was not properly kept; the track was laid neither straight nor level,



A CAR FOR CARRYING GRINDSTONE. THIS CAR IS BUILT TO CARRY A GRINDSTONE OF GREAT WEIGHT AND LARGE DIAMETER. THE MIDDLE PART WITH THE GRINDSTONE CAN BE TURNED SO AS TO FACILITATE LOADING AND UNLOADING. GAUGE, 23⅝ INCHES

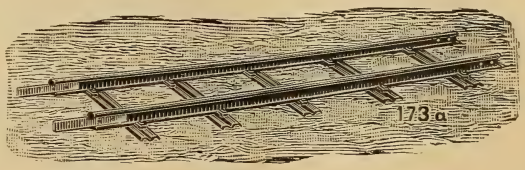
and owing to the height of the rails and the heavy ties, it was in the way of everybody. Waggons could not pass it, and horses stumbled over it. Taken altogether, the tracks and cars were a source of continual annoyance, and it was not surprising that the workmen disliked using them, and preferred wheelbarrows, or similar means of transportation; in fact, such a railway, notwithstanding its great cost, saved neither time nor money, and did not simplify matters, but, on the contrary, complicated them.



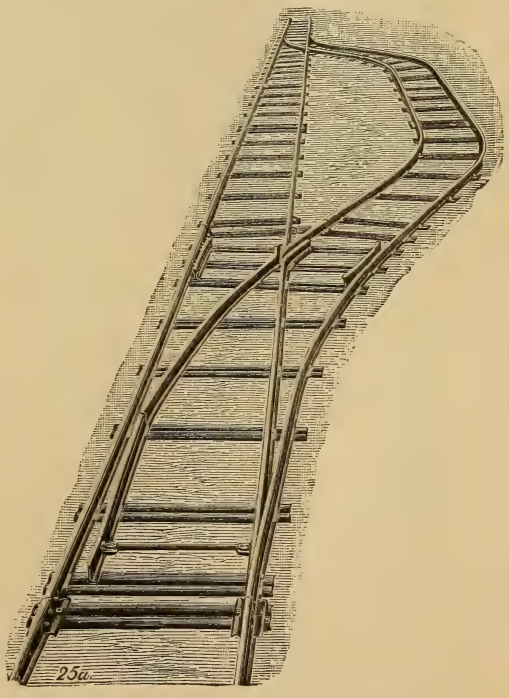
SPECIAL CAR FOR CARRYING BARRELS, WITH ADJUSTABLE END RACKS FOR LOADING AND UNLOADING

Now let us see how a thing like this is done to-day.

If, for a certain purpose, a medium of cheap transportation is wanted, all that is necessary is to write to a manufacturer of industrial railway equipments and state the case, telling him what the conditions are, *i. e.*, the material to be handled and quantity; the distance it is to be moved; special conditions to be overcome, etc. If, as in most cases, a narrow-gauge railway can be used, the manufacturer will recommend the kind of track material and the style of car to use. In other cases it might be necessary to send a rough sketch or drawing, showing the location. If necessary, the manufacturer will send his representative to talk the matter over, measure out distances, etc. Photographs, blue-prints, and sketches of what has been done in certain lines and how other people have solved the problem, the conditions of which were similar to the case in hand, will be shown, and the prospective customer's ideas and the manufacturer's experience will answer the purpose better than if one tried to work it out for one's self, or consulted someone who had never before done anything of the kind. It is a case for the specialist. Wherever these railroads are used one will be surprised to see how quickly they have paid for themselves, how reliably they will work, and how smoothly and nicely the work progresses, and how difficulties, which have been the source of great trouble for a long time, disappear. Track, curves and switches will fit and match and go where they belong, and the entire layout will be complete. On it the cars move easily and without difficulty, around curves and



SECTION OF INDUSTRIAL TRACK, COMPLETE, READY TO BE PUT DOWN



COMPLETE TURNOUT FOR AN INDUSTRIAL RAILWAY

over switches and turntables; the cars are of the proper dimensions to carry the goods and to be loaded and unloaded, and of suitable construction to answer the purpose, and enable loading and unloading within the least possible time.

At the end of the year when accounts are being balanced it will be seen that the output has been greater, while expenses have not been increased; or that the output is the same as before, but at a considerably less expense; that since the little railroad was installed there has been practically none of the annoyance formerly connected with the handling of the material, and that the buying and installing of the industrial railway system was one of the best investments made for a long time.

The illustrations accompanying this article show different parts of an industrial railway outfit made by Arthur Koppel, of New York.

The Compressed Air Power Plant at the St. Louis Exposition

THE central compressed air power plant at the St. Louis Exposition will contain two main compressing units; one cross-compound, two stage, Cincinnati-gear compressor, having 13 and 24-inch steam cylinders, 22 and 14-inch air cylinders and 24-inch stroke, with a displacement at 125 revolutions per minute of 1300 cubic feet per minute, and one cross-compound, two-stage, Meyer-gear compressor, having 12 and 20-inch steam cylinders, 18 and 11-inch air cylinders, and 18-inch stroke, with a displacement at 100 revolutions per minute of 530 cubic feet per minute. The first machine is to supply the general compressed air requirements of the Exposition, while the second is to supply the transportation exhibits. The larger machine is of special interest as being the first compressor of its type publicly exhibited, although a number of similar machines have been and are being installed in private plants. A 2800-foot machine is at the present time being placed in the Jersey City power house of the Central Railroad of New Jersey.

The general construction of one of these machines is shown in the illustration. The frames are of massive construction, with a long bearing on the foundation, while the steam and air cylinders, joined in the direct line of thrust by heavy cast iron housings, are also supported by bed-plates under their entire length, the weight of each side being thus taken on two large bearing surfaces extending to the ends of the machine, avoiding the objectionable features of overhung cylinders, and giving the compressor great stability. The general construction is characteristic of the best grade of engine work, and comprises removable quarter boxes and main bearings, steel forged connecting-rods, with wedge take-up, specially large crank and wrist pins and cast steel crossheads with adjustable babbitted slippers, top and bottom, working in bored guides. The reciprocating motion is of the simplest possible character, this simplicity in construction permitting low reciprocating weights without sacrifice of strength. These features allow satisfactory balancing, and, in connection with the long bearing on the foundations, insure an especially easy-running machine. The steam valve gear is of the Laidlaw-Dunn-Gordon four-valve type. Steam distribution is effected by means of short, double-ported slide valves, working at either end of the steam chest on a valve face as close as possible to the cylinder bore, the port volume being restricted as far as the large valve area will allow. The exhaust valves are of the Corliss rotary type, and are placed at the bottom of the cylinder. This construction has been followed in order to produce a valve gear having the essential advantages of a Corliss, namely, separate passages for the steam and the exhaust, with corresponding reduction in cylinder condensation, together with short, straight ports and small clearance. On the other hand, the complicated Corliss releasing gear, which is necessarily prejudicial to even moderate speeds, has

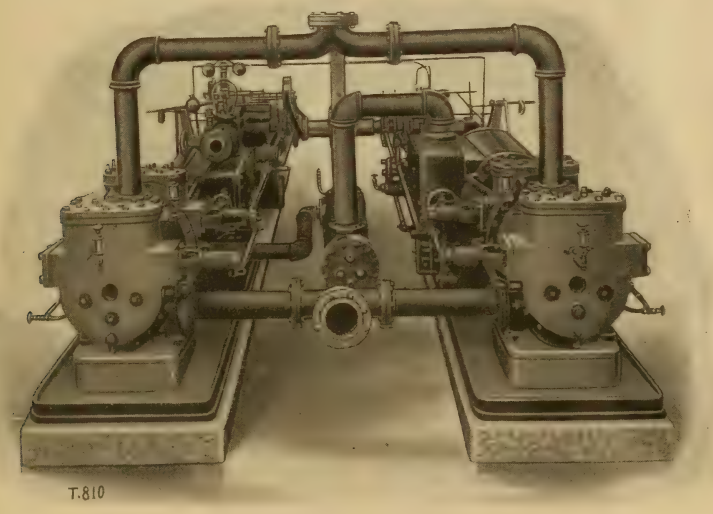
been eliminated, the action being positive throughout.

The air valve gear is, however, the distinguishing feature of this machine, combining in a very ingenious manner the positive action, noiseless operation and durability of the mechanically moved valve with the elasticity of the poppet valve. The noise and rapid wear of the poppet valve, due to the impact of the valves closing at the reversal of stroke, are eliminated by mechanically closing the passages underneath the poppet valve, and leaving a cushion of air upon which the latter seats. The three fixed points in the compression cycle, namely, the opening of the inlet, the closing of the inlet, and the closing of the discharge, are positively and mechanically controlled; the opening of the discharge, which is the only variable point in the cycle, is controlled by the automatic poppet valves, which are relieved, however, of the necessity for quick closing, and are consequently free from the objectionable features of noise and rapid wear.

These machines are built by the Laidlaw-Dunn-Gordon Company, of Cincinnati, Ohio, U. S. A.

A New Corliss Engine

WE illustrate herewith a new Corliss engine, which is being brought out by the Allis-Chalmers Company, of Chicago, from the designs of Irving H. Reynolds. The field of Corliss engine design has been so fully worked over in the past, and the accepted designs have become so simple, that no strikingly novel designs are to be expected. The present machine, however, represents the experience of twenty-six years in the building of Corliss engines, and combines all of the desirable elements of the best designs.



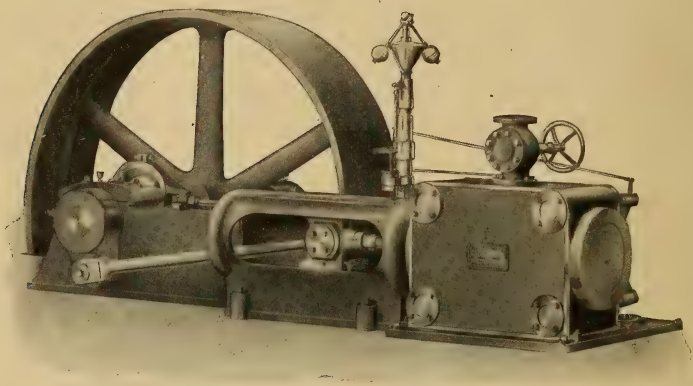
ONE OF THE TWO MAIN COMPRESSING UNITS FOR THE ST. LOUIS EXPOSITION. MADE BY THE LAIDLAW-DUNN-GORDON COMPANY, CINCINNATI, O.

Engines of the type illustrated are being built in seven sizes, ranging from 50 to 500 horse-power, and are designed for steam pressures up to 150 pounds. They are built with somewhat shorter strokes than have heretofore been customary in Corliss engines, with the idea of economising in space and making the construction more rigid. The speeds are also somewhat higher than usual, ranging from 110 to 150 revolutions per minute, although these speeds are not higher than those at which the Reynolds-Corliss engines of older design are frequently operated.

The frame is cast in one piece with the slide, the construction being of the box type, resting on the foundation for its entire length. The main bearing shells are bored into the frame, thus insuring a solid bearing, and also permitting the easy removal of the shells by rolling them out around the shaft. The slide is of the barrel type with bored guides. The crosshead is fitted with babbitt faced shoes with wedge adjustment. The piston rod is screwed into the crosshead and held firmly with a steel lock nut. The cylinder, of the round-cornered type, is fitted with double-ported steam and exhaust valves, lagged with planished steel. It is set on a cast iron base-plate, which extends under the valve gear and serves as a drip pan.

The valve gear is of the usual Reynolds Corliss type, except that the wrist plate of skeleton pattern is fitted with a new type of disconnecting device, which, while clamping the hook rod firmly, is very easily detached by hand. The dash pots, of the differential plunger type, are without leathers or packing of any kind.

In brief, the engine is strong, simple and compact, and while nothing has been added for ornamentation, nothing contributing to economy or durability has been omitted, and the machine should find a large sale among power users who appreciate quality.



A NEW CORLISS ENGINE. MADE BY THE ALLIS-CHALMERS CO., CHICAGO, ILL.

The Jeffrey Manufacturing Company, of Columbus, Ohio, has published a catalogue on mining machinery especially devoted to rock and coal drills. The "New Jeffrey Badger" steam or compressed air drill is a combination of the "Badger" drill, formerly manufactured by the Phillips Rock Drill Company, and such improvements in the design and material as the present manufacturers have made. Many illustrations are shown of this drill and others operated by electricity and hand-power. Electric mine locomotives, pumps, hoists, coal cutters, conveyors and other machinery are shown. Prices are also given.

A cloth-bound catalogue of pocket size has been issued by the Perkins Electric Switch Manufacturing Company, of Bridgeport, Conn. It contains many illustrations of switches, lamp sockets, plugs and receptacles, cut-outs and incandescent lamp fittings. The telegraph code included will be valuable to the company's customers.

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